TECHNOLOGIES TO MAINTAIN BIOLOGICAL DIVERSITY

Volume II--Contract Papers

Part D: Natural Systems - International

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13. Technologies to Maintain Tree Germplasm Diversity
    (Frank T. Bonner)

14. Causes of Loss of Biological Diversity
    (Norman Myers)

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Contract Paper No. 1

Status and Trend of Natural Ecosystems Worldwide

Jeremy Harrison
Conservation Monitoring Centre

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STUDY OF THE STATUS AND TRENDS OF IN-SITU CONSERVATION OF BIOLOGICAL DIVERSITY WORLDWIDE

A paper prepared for the

Office of Technology Assessment,
Congress of the United States

by

Jeremy Harrison
IUCN Conservation Monitoring Centre
219c Huntingdon Road
Cambridge CB3 ODL
United Kingdom

International Union for Conservation of Nature and Natural Resources

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- An introduction to the work of the Protected Areas Data Unit, IUCN Conservation Monitoring Centre

ABSTRACT

The principal aims of this paper are to illustrate the status and trends of in situ conservation of biological diversity; to look at the information available and some of the methods of managing it; and to review what is needed to both improve information availability and information management. The paper begins with a brief description of the database used for the analysis of status and trends, that of the IUCN Conservation Monitoring Centre (CMC). The work of CMC on protected areas is carried out in cooperation with IUCN's Commission on National Parks and Protected Areas. Data collection methods are also described, as is the requirement for information at all levels.

Some classification of the information is necessary. It is relatively straightforward to provide lists of protected areas within a country, arranged by definition (national park, nature reserve, etc.), but this fails to show three vital things, coverage of natural features, management objectives, and how well those objectives are being met. It is therefore important to arrange the information to make it more comparable, and so that it can be used to assess coverage of the world's natural features. IUCN uses global biogeographic maps in making an initial assessment of biogeographical coverage. These are available for both terrestrial and marine areas, though CMC has yet to apply the marine biogeographic classification. Some of the problems of using such maps are discussed. Classification of protection is also necessary to indicate actual protection of a site (rather than the protection implied by a site's name). IUCN have developed a classification of management categories which is employed here.

The analysis begins with a general description of the rates of growth of the world's protected areas network. These figures are then split to illustrate differences between developed and developing countries, between different biogeographical realms, and between different biome types (e.g. mountains and tropical humid forest). This illustrates some large differences, though its value is probably historic rather than predictive. The value of an international database in presenting the opportunity for international comparison is also introduced. Data derived from various sources is used here to illustrate differences in protected area network between countries in South America. However there are problems in making even this type of analysis, and these are discussed.

The terrestrial biogeographical map adopted by IUCN is then used to study world coverage of protected areas more closely. In this way a number of gaps

within the system are highlighted. Lists of biogeographic provinces either without protected areas, or with few areas or a small area protected are given. Problems with this approach are touched on, and some of the anomalies thrown up by such analysis illustrated. The method does however indicate the patchy nature of current protection and indicate areas that may warrant further attention. Clearly application of biogeographical approaches at a lower level can be correspondingly more sensitive, and a number of differing methods are briefly described. This is followed by a discussion of the problems and approaches used with ecosystems which are azonal.

It is one thing having the information available, but it is quite another to actually ensure good use of it. Various conservation groups that make use of this type of data at the international level are briefly described, as well as the use made by agencies such as the World Bank. The need for availability and use of the information at all levels is also discussed, along with the need for accessibility. A number of recommendations are made.

The final topic dealt with is the potential for improving the database. Discussion first deals with collection, verification and compilation of data, and makes a number of recommendations applicable to database efforts at all levels. This is followed by discussion relating to database management, and in particular methods of data handling which would greatly improve the value of current databases (particularly those at the international level, and CMC specifically). Topics covered include geographical information systems, habitat classification, ecosystem inventories, species inventories and surveys of the effectiveness of protected area management. Recommendations made here cover not only further development of the IUCN database, but also national and local databases, and the necessary basic research.

Recommendations are drawn together and rearranged/rewritten in a summary under five headings: availability of information; national and local conservation databases; improvement of information exchange; IUCN's international database; and use of the information. Perhaps the most important point to make in conclusion, however, is that if U.S. agencies, institutions etc. encourage and support the use of environmental data in decision making, and use such data in their own decision making processes, this should in itself encourage the development of the information base at all levels. This will then provide improved tools both for making new planning decisions, and reviewing the effects of previous decisions. Further use of such information within the U.S. will hopefully also lead to further use of environmental information within planning and management elsewhere.

INTRODUCTION

> "In situ conservation (natural ecosystem or habitat conservation) entails the management or conservation of genetic resources within their natural or original habitat". (Oldfield, 1984)

Clearly any review of the in-situ conservation of biological diversity needs to be prefaced by three key questions:

a) What do we mean by biological diversity in this context;
b) Why must it be conserved; and
C) Why should it be conserved in situ?

As this is one of a number of papers being prepared for an assessment of Technologies to Maintain Biological Diversity it is assumed that the first two questions need not be addressed further here. The questions are, of course, also addressed by a number of key texts on genetics, conservation and evolution (e.g. IUCN, 1980; Soulé and Wilcox, 1980; Frankel and Soulé, 1981; Schonewald-Cox et al, 1983; Oldfield, 1984), and by innumerable papers and reports. It is, therefore, taken as read that conservation of biological diversity is important. The third question, however, is rather more pertinent to this paper.

In essence the reasons for needing to conserve biological diversity (or genetic resources) in situ are as follows:

1. It is not usually possible or practical (or indeed desirable) to protect ex situ the entire gene pool of a population or species. It therefore follows that not all of the useful genetic material will be available.
2. Genetic traits, and specific adaptations exhibited by 'resource' populations are acquired through dynamic evolutionary processes within natural environments - by definition a continuous (and continuing) process. Removal of members of a population from their natural environment will lead to a total change in the dynamic interactions a population undergoes. This not only results in a reduction in the gene pool available for adaptive evolution (limiting the possiblitites), but also removes the natural influences on the genetic character of the population, thereby altering the rates and directions of genotypic development.
3. Finally there are numerous problems with both effective sampling of the available genetic material, and its maintenance ex situ (as a result of both physical limitations and technical difficulties).

It must therefore be apparent that not only is in situ conservation usually more effective, but it is also usually more cost-effective. Unless one is selecting specific genetic traits within a population for defined purposes, the task of conserving genetic diversity becomes more difficult where genetic material is removed from its natural environment? This is not to deny the importance of ex situ conservation in a variety of circumstances (particularly in genetic improvement programmes, and within populations of species which are no longer 'viable' in natural situations) but it cannot be denied that most species cannot be conserved effectively by available ex situ methods.

What then is meant by in situ conservation? If we take the definition used by Oldfield (1984) above, what is immediately apparent is the wide range of conservation 'methods' this encompasses: from international conventions on protection of sites and species, to preservation of the habitat of the Californian condor, and from 'Save the Whale' campaigns to the formal establishment and management of protected areas and protected areas systems. It is apparent that this paper cannot cover all of these activities, nor is it intended that it should. Discussion will therefore be restricted to the status and trends in the protection of biological diversity by protected areas and protected area systems.

THE DATABASE

The primary interest in this paper is the status and trends in in situ conservation at a global level, and therefore it would perhaps initially seem that only the international database level needs to be discussed. However, a good supply (i.e. availability and continuity) of information is essential, and therefore when assessing the international level one must also consider the local.

Clearly there are at least three levels at which information needs to be available for effective management of natural resources within protected areas:

a) information on each individual area needs to be available within the area;
b) information on all areas within a country needs to be available within that country; and
c) information on all the world's protected areas needs to be available within an international database.

In each case the information is most valuable where it is managed on one site, and it should be emphasised again that in the first case it is generally desirable that that site be within or very near the individual protected area concerned. (It should be noted here, and in other discussions in this paper, that the term database need not necessarily imply the use of computers.)

Obviously each of these databases manages a different set of information, with points of overlap. Within any given protected area there is a wide range of information available - some of it very specific. A subset of this is required by the protected areas system database - which is made up of the subsets of information from each protected area compiled together with other national information (vegetation patterns, geology, weather and climate, etc.). It is a subset of this particular database that is needed at the international level, compiled with similar information from every other country and with information at a global level on aspects of vegetation, climate, and so on.

The primary concern in this paper is the availability of this information within an international database. It is only by this means, for example, that it is possible to provide overview papers such as this one, which can indicate potential gaps within protected areas systems, and indicate status and trends world-wide. Other reasons are provided in earlier studies (e.g. Harrison *et al*, 1982), and include the provision of information to conservation agencies to help in making judgements on resource allocation, and the provision of introductory information to aid agencies on the conservation issues/problems within areas they are working or considering working. Clearly, without the information being available at the national level, it is extremely problematic to collect it at international level, and there is a need for good national databases, in turn leading to a need for good information handling procedures at an individual area level, but it must not be forgotten that information needs to be used in decision making and management at all levels. Most decisions are made at the local or national level, and hence the prime concern of these databases must be input information for use in these decision making processes. Provision of information outside this requirement will always be of secondary importance. It goes without saying that for good information flow to occur there must be both a willingness to cooperate with the need for information flow at all levels, and sufficient funding within these operations to allow for this process.

The international database

IUCN's Commission on National Parks and Protected Areas (CNPPA) has been collecting information on protected areas for more than 20 years, for use in both its programme development and its publications. Since 1959 IUCN has been charged by the United Nations with maintenance of a United Nations List of National Parks and Equivalent Reserves (e.g. IUCN, 1985). Over the years the information management role has increased to the extent that in 1981 CNPPA set up the Protected Areas Data Unit (PADU) to manage the information. This unit is now a part of the Conservation Monitoring Centre (CMC), a division of the IUCN Secretariat.

The processes of information collection are many and varied, depending ultimately on how easily management authorities in each country are able to pass on the information needed, and how accurate (or reliable) that information is. The first step is close cooperation between PADU and CNPPA at the latter's regional meetings of parks managers and experts, which are held twice a year in different parts of the world (this year in India and Western Samoa, etc). PADU draws together the information currently available for the region in question, taking 'draft directories' of the information to the meeting for review by the participants.

However, we find that (for a variety of reasons) information obtained at meetings in this way is not usually sufficient, and correspondence must be maintained not only with the management authorities within each country, but also with numerous other individuals and organizations. It is also essential to be aware of the published literature on protected areas within each country, and of the numerous reports produced by other international agencies such as the FAO.

In other words, the collection of information is a very active process, and necessarily a labour-intensive process. It is also time consuming, especially when one considers that all information received must be compared with information already available, and then incorporated as appropriate. If one were to wait for the information to come flowing in, and were to believe everything that came, the resulting database would be rather poor both in terms of information content and accuracy.

The current database content

Measures needed to improve both data collection and management are dealt with in a later section, but what sort of information is currently available, and how good is it?

PADU currently has basic information on computer for between nine and ten thousand protected areas. This is, of course, nowhere near the total number of protected areas in the world: Sweden alone has 1200 nature reserves, and 1300 natural monuments (Esping and Larsson, in litt). Australia has 1248 nature reserves (Wilson, 1984), and the New Zealand register of protected natural areas includes some 1660 sites (Department of Lands and Survey, 1984). The PADU files essentially contain information on those sites of over 1000 hectares which are protected by the 'highest competent authority' (except islands, where the size cut-off is 100 hectares).

However, it is fair to say that the information held for some categories of protected area is much better than for others. The database contains much better information on national parks and nature reserves, and even natural monuments, than areas such as forest reserves and game management areas, which, although not designated for nature protection are usually designated for nature conservation. We have virtually no information on other types of 'restricted area' such as fishing reserves, or rock lobster sanctuaries (South Africa).

Moreover, PADU has relatively little information at present on 'privately' protected areas, i.e. those areas protected by individuals or non-governmental organizations. This may not seem too serious until one realises that this excludes the many important sites protected by the Nature Conservancy (for example) in the United States, or the Royal Society for the Protection of Birds or the National Trust in the United Kingdom.

That being said, PADU has reasonably complete lists of protected areas of over 1000 hectares (100 for islands) which are protected primarily for nature conservation purposes by the 'highest competent authority'. These are not the totally accurate lists which we should have available, and which we are working towards, but certainly lists that are good enough to demonstrate all the key points brought out in this paper.

Clearly PADU does not solely maintain lists of protected areas, but has on file information on the protected areas systems of each country, with basic details of legislation and administration, as well as further details of each individual site; location, physical features, flora and fauna, management, problems, etc. This is described more fully in the attached paper. However, the most crucial information, information that is often the most difficult to obtain, is not what is protected and where, but determining how well the area is protected, and if it is achieving its objectives. PADU, working with CNPPA, has recently reviewed the information on Africa (IUCN, in press), for example, and as a result of this work our appreciation of the conservation status of a number of African sites has changed. Assessment of this sort is continuing, but currently in a subjective rather than objective manner because of the patchy nature of the information. This is dicussed further below.

CLASSIFICATION AT A GLOBAL LEVEL

It is relatively straightforward to provide lists of protected areas within a country, arranged by definition (national park, nature reserve, etc.), and even mapped, but this fails to tell us three vital things - coverage of biological and geographical features, management objectives, and how well those objectives are being met. It therefore becomes important to try to arrange the information so that it can be made more comparable across the world, and so that it can be used to assess coverage of the world's natural features.

Classification and mapping of environments

A major objective of the protected area system of the world is the maintenance of the diversity of species and ecosystems, but the listing of protected area coverage by country provides little information on how well natural ecosystems are being conserved. The problem of determining how well this objective is being met is approached through biogeography, the science of distribution of species and ecosystems.

Though a useful tool, biogeography has its limitations; many of the world's species remain undiscovered (let alone described), species distributions remain unknown in many parts of the world, and the mapping of natural ecosystems has been rendered even more difficult by man's alteration of the environment. Further, botanists and zoologists have their own ways of looking at species distribution which can make it difficult to reach an agreement on broad patterns of distribution.

However, biogeographical maps for assessing the coverage of the world's ecosystems by protected areas are needed now, not when all of these problems have been solved. IUCN has therefore commissioned the development of two systems for assessing coverage, one for terrestrial environments (Udvardy, 1975) and one for marine and coastal environments (Hayden et al, 1984).

Udvardy (1975), following on from the earlier work of Dasmann (1973) and IUCN (1974), divides the land areas of the world into eight major realms, each of which is divided into a number of provinces (193 in total). Each province is characterised by a particular biome type (of which Udvardy describes 14). For example, the Sequoia National Park in California, within the Nearctic Realm, is in the Sierra-Cascade Province, which is characterised by a mixed mountain and highland system biome.

Hayden et al (1984) divide marine and coastal environments into Ocean

Realms, Coastal Realms, and Marginal Seas and Archipelagos, with 40 resulting Faunal Provinces along the coastlines. One of the principal differences in using this system is that only the faunal provinces are continuous, while ocean realms, coastal realms, and marginal seas and archipelagos are all disjunct in nature.

For further information on either system the publications concerned should be stuoied, as it is virtually impossible to understand their respective approaches without studying the associated maps.

Although Udvardy (1975) in defining a biogeographical province uses the definition given by Dice (1943) for his biotic provinces as areas characterised by peculiarities of vegetation type, ecological climax, flora, fauna, climate, physiography and soil, it is clear from his work that lack of source material and data resulted in an emphasis on the use of vegetation patterns in defining provinces. A wider range of information is now available, and this has led to IUCN commissioning an update from Udvardy. It is anticipated that this will be completed soon.

Udvardy's approach is dependent largely on the analysis or interpretation of the biological/ecological effects of environmental factors. This is rather different from Hayden et al's (1984) approach for the coastal and marine environments where the classification is based on the assumption that the geophysical structure of the environment gives rise to a particular ecological response.

Bailey (1976, 1980, 1983) working on the deliniation of ecosystem regions for North America uses macroclimate for broad-scale subdivision of the continent. Following Crowley (1967) these areas are termed domains and are subdivided into divisions, again on the basis of climate criteria (though the divisions correspond to areas with definite vegetational affinities, and usually the zonal soils are also related). For example North America is split into four domains, polar, humid temperate, dry and humid tropical, the dry domain into semiarid steppe, semiarid steppe regime highlands, arid desert and arid desert regime highlands. The delimitation of these domains and divisions is largely based on Köppen (1931).

Divisions are in turn divided into provinces on the basis of the climax plant formation - often coincident with the major soil zones, and provinces are futher subdivided into sections on the basis of differences in the composition of the climax vegetation type. So, for example, the arid desert division is divided into the Chihuahuan and American (Mojave-Colorado-Sonoran) desert provinces, while the Chihuahuan province is divided into the

Grana-Tobosa and Tarbush-Creosote Bush sections. Further subdivision would be carried out using criteria such as land-surface form, soils, vegetation associations etc. though such subdivision is beyond the scope of Bailey (1976, 1980).

Bailey, who works for the U.S. Forest Service, is now hoping to extend his work to map domains, divisions and provinces for the world at a scale of 1:25,000,000 (as well as investigating more closely the links between ecosystem boundaries and soil distributions). This would supplement Udvardy in two ways, firstly the ecosystem regions would be based on correlation of several landscape features hopefully leading to the identification of units of greater ecological relevance, and secondly this would give a more detailed breakdown of the world's ecosystems.

Whatever systems are used, the classifications provided offer nothing more than an approximation based on a series of compromises. Any global biogeographical or biophysical mapping approach should only be regarded as a working document open to adaptation and modification. It should also be noted that completely consistent land and sea classifications are probably not possible (Hayden et al, 1984), though Bailey and Cushwa's (1982) ecoregions would seem to tally more closely with the proposed marine and coastal classification than Udvardy's (1975) provinces (Hayden et al, 1984), presumably because of a greater use of causal environmental factors in Bailey's approach (Bailey, 1983).

As it is the only biogeographical system covering the world, Udvardy (1975) is used here to make an assessment of coverage of the world's environments by protected areas. Similarly Hayden et al (1984) would be the system used for marine and coastal environments.

Caution: *What must be appreciated in using these approaches, however, is the very basic nature of the method. These maps make no account of actual existing environments (e.g. how much of the tropical humid forest actually remains), nor are they fine enough to provide more than a rather general overview. It should also be noted that such systems only cover zonal features of the environment - azonal features such as wetlands, coral reefs, etc. cannot be covered, by definition. These problems, and others, are discussed further below. Also discussed below is the need for much more detailed information available on the distribution of actual ground features (including vegetation, land forms etc.), and information on distribution and conservatiuon status of a wide variety of species 'of conservation concern'.*

Classification of protected areas

Around the world there are many different designations of protected area. In Kenya, for example, the terms used include national parks, national reserves, nature reserves and forest reserves, whilst in Spain, national parks (parque nacional), nature parks (parque natural) and national hunting reserves (reservas nacionales de caza). There are 'no hunting areas' in Thailand and game management areas in Uganda, while similar areas in Kiribati are designated wildlife sanctuaries - very different in conservation terms from the wildlife sanctuaries of India. In the same way the designated national parks of the United Kingdom are in no way similar to the national parks of the United States.

In an attempt both to clarify this situation, and to promote use of the full range of protected area 'types', IUCN (1978; 1984) identified a series of ten management categories defined according to management objectives (categories nine and ten being biosphere reserves and world heritage sites respectively). Although these ten categories have 'names' associated with them (eg. strict nature reserve, national park), categories are assigned according to management objectives, and not according to the designation of the area (see Table 1). In other words the national parks of the United Kingdom are placed under Category V (protected landscapes and seascapes) rather than Category II (national parks). This facilitates international comparisons, providing a framework into which all protected areas should fit. It also enables us, for the purposes of this paper to define which areas will be included in the analysis, those in Categories I through V, the areas of particular interest to CNPPA (IUCN, 1978).

For various reasons, any one 'type' of protected area defined by a particular country could belong to more than one category - this means that, of a number of national parks within any one country, some could be within Category II, and some within Category V depending on the objectives of their management. Within New Zealand, for example, scenic reserves can be in any of Categories I through IV, scientific reserves in Category I or III, and wildlife refuges in category IV or VIII (Department of Lands and Survey, 1984). It should also be noted that the system is currently used by IUCN according to the application of the management objectives, and not necessarily according to a sites legal definition (though Wetterberg et al (1985), for example, apply the defined categories according to management intent rather than management practice). To take an example from a country with some fairly severe management problems, Angola has six designated national parks, six designated reserves, and one nature park. Of these only one area is listed as Category II, three as Category IV and one as Category V (IUCN, 1985; in press). Within the other areas, the management authorities have too many problems to enable them to achieve their management objectives (Braga, pers. comm., 1983).

Caution: As is apparent from these examples, the system is currently applied in a way which attempts to represent both the management objectives of an area, and how well these objectives are being achieved. This has its problems. There is a basic need to separate out these two aspects so that we can look at both the management objectives, and the effectiveness of an area independently. This is discussed further below.

WORLD COVERAGE OF PROTECTED AREAS

Growth of the Protected Areas Network

Since the first two national parks were established in the 1870s, around 3500 areas have been created which IUCN's Commission on National Parks and Protected Areas considers to be of sufficient status to be included in the 1985 United Nations List of National Parks and Protected Areas (IUCN, 1985). The total area protected includes some 4.25 million square kilometres. The rate of this growth is illustrated in Figure 1, which shows both the number of sites protected and the total area of these sites, plotted cumulatively from 1870. Figure 2 illustrates the number and area of sites added during each five year period since 1870.

Little needs to be said about these figures. Growth was slow in the early years, but began to pick up in the 1920s and 1930s, before being brought almost to a halt by the Second World War. By the early 1950s, momentum had begun to gather again and the decade from 1970 to 1980 saw about twice as many new areas created as had existed in 1969. The growth rate seems to have slowed a little over the last few years.

This rather crude overview can be broken down a number of other ways to illustrate particular aspects of this development. For example, Figure 3 shows the differences in rate of establishment between the 'developed' world and the 'developing' world (based on whether the country is a member of the Organisation for Economic Co-operation and Development (OECD) or not). What is, perhaps, most interesting here is the difference in shape between the curves illustrating the number of areas protected, which increases slowly and steadily for OECD countries, but which has a very distinct break in it (around the second world war) for non-OECD countries. In fact the number of areas protected in non-OECD countries has remained below that in OECD countries right up to around 1970, but not only are numbers now higher, the rate of establishment is also greater. It is also apparent that if the Greenland National Park (70,000,000 ha) were removed from the OECD data the average size of areas in OECD countries would be considerably less. This illustrates the importance of looking at both size and number of protected areas.

Figure 4 categorises the figures by biogeographical realm, and clearly demonstrates differences. In the Afrotropical Realm, for example, while the number of protected areas established has increased steadily to around 360 in 1982, the average area protected is much greater than that in any realm other than the Nearctic (and that only because of the large effect of the inclusion of the Greenland National Park in 1974). These graphs also illustrate large differences in timing of the development of protected areas within each region. One should note, for example, the differences between the Australian and Nearctic realms, and the sudden increase in the Indomalayan realm after 1970.

A closer look at the situation within each biome can also be illustrative. For example, Figure 5 shows the situation in each of four major biomes defined by Udvardy (1975): tropical humid forest (biome 1); temperate broad-leaf forests (biome 5); mixed mountain and highland systems (biome 12); and mixed island systems (biome 13). The differences are very pronounced. Biome 5 (temperate broad-leaf forests), for example, covers large areas of the eastern United States, and much of Europe; highly populated areas, and hence containing a fairly high number of small areas with a steady pattern of development. The development pattern is the same in biome 12 (mixed mountain and highland systems) but starting to increase nearly 10 years earlier, and having much larger areas. Development of protected areas in both these biomes began earlier than in either biome 1 (tropical humid forest) or biome 13 (mixed island systems) where numbers of protected areas did not really increase until after 1920. Particularly noticeable is the sudden increase in the area protected in the tropical humid forest biome from 1970 onwards, indicating the establishment of much larger protected areas since 1970. Analysis of this work continues, and will be reported elsewhere.

Comparisons between countries

One particular advantage achieved with an international database is the opportunity for international comparison. Table 2 gives the number of areas protected in South America in IUCN management Categories I-V, and their total area, also presenting these figures as a function of the area of the country, and its population. The data are derived from various national reports, from information provided at the 18th Working Session of CNPPA, and from Wetterberg et al (1985). The wide differences between one country and another even within one continent are quite obvious.

However, care must be taken in making such comparisons in the absence of background information as hard figures such as these can be misleading. For example, although undoubtably valuable conservation areas, the national reserves of Peru are excluded. This is because national reserves in Peru, while being areas designated for protection and propagation of species of wildlife whose conservation is of national interest, are also areas where utilization of products is being carried out by the State. Thus these areas do not therefore fit into Categories I through V (Wetterberg et al, 1985).

Biogeographical Coverage - Global Review

The first approach to assessing coverage of the world's biota by protected areas using Udvardy (1975) is to examine coverage by biome, and by biome within realm. These figures are presented in Table 3. It is important to appreciate that biome type is not synonymous with habitat type; a protected area within a tropical humid forest biome may not necessarily contain tropical humid forest, and an area containing tropical humid forest could occur in another biome altogether (such as Mixed Island Systems).

It is also important to realize that the total area of each biome in each realm has not yet been determined with sufficient precision to assess percentage coverage. This can hide important differences in the figures. There are, for example, 122 areas covering 84,634 square kilometres in the Temperate needle-leaf forests/woodlands biome in the Palaearctic, but only nine areas covering 521 square kilometres in the mixed island systems biome. It would obviously be misleading to assume that temperate needle-leaf forests/woodlands are therefore better protected than the mixed islands system biome in the Palaearctic, since most of Asia between 55°N and the Arctic Circle and much of Europe, is within this biome, while only the Macronesian Islands and the Ryukyu Islands (in total about 17,820 square kilometres) are defined by Udvardy as within the mixed island systems biome; less than the area of Temperate needle-leaf forest on the Soviet island of Sakhalin! In the same way, care should be taken when making comparisons within biomes.

Comparison of the biogeographic provinces suffers from the same limitations noted for biome comparisons; a 5000 hectare protected area in the relatively small Malagasy Thorn Forest (3.10.4), for example, would protect a much larger section of that province than an equivalent-sized reserve would in the huge Somalian province (3.14.7).

In fact there are protected areas within all biomes, although the number of areas and the total area protected varies considerably. Turning to coverage of biomes within realms, the only occasion where no protected areas are recorded is in the Lake systems biome within the Neotropical Realm. Only one lake, Lake Titicaca, is involved. It would be misleading, however, to assume that this lake was completely unprotected, as the Reserva Nacional de Titicaca extends along about 10% of the Peruvian shore. (As noted above, Peru's national reserves do not fit into IUCN management Categories I-V.)

Further analysis of the figures based on a knowledge of the area of each biome is clearly required, one would be concerned, however, at the low area protected (and the low numbers of protected areas) in certain of the biomes within particular realms (following IUCN, 1980, defined as having less than 1000 square kilometers protected). These are:

Temperate broadleaf forests	Neotropics	(Province 22)
Cold winter deserts	Neotropics	(Province 26)
Temperate Grasslands	Neotropics	(Province 31-32)
Mixed island sysytems	Palaearctic	(Province 40-41)
	Afrotropical	(Province 23-25)
Lake systems	Palaearctic	(Province 42-44)
	Afrotropical	(Province 26-29)
	Neotropical	(Province 47)

However, one should note that but for the Cold winter deserts of Patagonia, and the Temperate Grasslands of Argentina, Uruguay and southern Brazil, these are all relatively small provinces. In the case of the Mixed Islands system in the Palaearctic, for example, nearly 3% of the biome is already receiving protection. It should also be noted, however, that there are fewer than five protected areas within the majority of these areas.

Analysis by biogeographical province is rather more 'fine grain', and, therefore, as expected more gaps in the system are highlighted (Table 4). Provinces without any areas within our definition are:

Arctic Archipelago	*1.15.6*	*Greenland Tundra*	*1.16.6*
Lake Ladoga	*2.42.14*	*Lake Baikal*	*2.44.14*

Ascension/St Helena	*3.23.13*	*Lake Rudolf*	*3.26.14*
Lake Tanganyika	*3.28.14*	*Burman Rainforest*	*4.4.1*
Laccadive Islands	*4.17.13*	*Maldives/Chagos*	*4.18.13*
Pacific Desert	*8.24.7*	*Argentinian Pampas*	*8.31.11*
Revilla Gigedo Island	*8.42.13*	*South Trinidade*	*8.46.13*
Lake Titicaca	*8.47.14*		

There are some changes which will be apparent from Harrison et al (1982), in particular the appearance of some provinces in this list that were not in it before. The two Africa Lakes are added as the reserves on their shores protect little of the lakes themselves (Lake Baikal and Lake Ladoga also have reserves on part of their shorelines). Although there are legislated protected areas in Burma, it has been reliably reported that these are currently not effectively managed because of a number of difficulties within the country (and hence their categories have been modified within our files). Both the provinces in Peru have national reserves, which have also had their categories modified in our file for the reasons stated above.

30 provinces have 5 or fewer protected areas and an area of less than 1000 sq.km protected. These are:

Tamaulipan	*1.10.7*	*West Anatolian*	*2.13.5*
Atlas Steppe	*2.28.11*	*Hindu Kush Highlands*	*2.37.12*
Szechwan Highlands	*2.39.12*	*Ryukyu Islands*	*2.41.13*
Aral Sea	*2.43.14*	*Malagasy Thorn Forest*	*3.10.4*
Comores/Aldabra	*3.24.13*	*Mascarene Islands*	*3.25.13*
Lake Ukerewe (Victoria)	*3.27.14*	*Lake Malawi*	*3.29.14*
Ceylonese Rainforest	*4.2.1*	*Seychelles/Amirantes*	*4.16.13*
Cocos-Keeling/Christmas	*4.19.13*	*Taiwan*	*4.27.13*
Micronesian	*5.2.13*	*Central Polynesian*	*5.5.13*
East Melanesian	*5.7.13*	*Insulantarctica*	*7.4.9*
Campechean	*8.1.1*	*Brazilian Planalto*	*8.9.2*
Guerreran	*8.14.04*	*Chilean Araucaria Forest*	*8.22.5*
Chilean Sclerophyll	*8.23.6*	*Patagonian*	*8.26.8*
Cuban	*8.39.13*	*Cocos Island*	*8.43.13*
Fernando de Noronja	*8.45.13*		

A further 10 provinces have less than 1000 square kilometers protected but have more than 5 protected areas, while a further 29 have 5 or fewer protected areas but an area of over 1000 square kilometers protected. Again there are some anomalies, all of Cocos Island is protected, for example, as is a sizeable part of Christmas Island, parts of several of the Ryukyu Islands and the Atol das Rocas close to Fernando de Noroja. Most of the islands of Insulantarctica also already receive a fair degree of de facto protection (Clark and Dingwall, 1985).

Nevertheless, this rather crude application of what is a rather crude tool suggests that a number of these provinces may be poorly protected, and therefore may be areas where attention should be focused. This should not be interpreted to mean that it is more important to establish a protected area in Lake Ladoga than in the Congo rainforests for example (as might be understood from Map 3 in the World Conservation Strategy, IUCN, 1980), this sort of decision would depend on numerous other arguments such as the vulnerability and fragility of the biome type, and the threats (and hence the urgency).

This brief survey shows us that the coverage is patchy, but to determine exactly how patchy, more analysis of the figures is required, based on accurate estimations of the size of the provinces; this work is in progress.

Turning to the marine biophysical approach of Hayden et al (1984), it has not yet been possible to carry out the research necessary for a similar review of marine and coastal protected areas, though the necessary information is available to CMC. IUCN is actively seeking funds for this project.

Biogeographical coverage - application at the local level

It is clear that the global biogeographic approach provides useful information primarily at the global level. For application of this information on the ground, we need to turn to either the regional or national level where the same biogeographic principles can be applied with considerably greater precision, yielding proportionally more useful results (though again, in many cases, much of the basic information such as species distribution, remains to be collected).

Various countries have produced biogeographical maps for use in the assessment and planning of their own protected area systems, and various assessments of coverage have been made (or attempted) for a wide range of countries. (See for example recent papers on Pakistan, Indonesia and India in Thorsell, 1985a).

Rodgers (1985) describes a biogeographical classification for India which has been designed by the Wildlife Institute of India for conservation planning purposes. The Institute is coordinating a national inventory of protected area coverage in relation to this biogeographical approach. Based on the results of this inventory, and the described biogeographical approach, a 'consultant team' will be able to make recommendations concerning the protection (or increased protection) of particular areas.

Wetterberg et al (1981) describe how the protected area coverage of the Amazonian region was assessed using the phytogeographic regions of Prance (1977). This was followed up by the definition and mapping of 'Pleistocene refugia' (in effect centres of endemism and/or diversity) for birds, lizards, butterflies and woody plants, derived from the available literature. The points of overlap were noted, and after further refinement (taking into consideration rural development plans and other factors), 30 general areas were identified where efforts to establish protected areas could be concentrated. Brazil was able to incorporate much of this work into its protected areas system plan (IBDF, 1982), and several protected areas (covering several million hectares) have since been set up - mainly within recommended regions.

Terborgh and Winter (1983) use the distribution patterns of bird species having ranges of less than 50,000km^2 in Ecuador and Colombia to make recommendations on the siting of reserves within these countries - based on the premise that such species (which over the continent as a whole comprise about a quarter of the terrestrial avifauna) are more vulnerable to deforestation than more widespread species. Within these two countries, 156 such species were identified, and their distributions mapped, and then a 'concentration map' was prepared by superimposition of all individual species maps. Zones of maximum overlap obtained are described as areas obviously meriting protection in a rational conservation plan, though the authors also note areas of importance not immediately apparent from this approach. Terborgh and Winter (1983) clearly show that while a large majority of these species could be protected in a few well-situated reserves, virtually none of the crucial areas are contained within the existing or proposed protected area systems of either country.

Huntley and Ellis (1983) used the then available vegetation maps of southern Africa (Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia and Zimbabwe) to estimate the total area of each country covered by each vegetation type (out of a total of 189). Maps of the protected areas in each of these countries were then accurately plotted on the vegetation maps so that the total area protected of each vegetation type in each country could be estimated. This analysis served to highlight the tremendous emphasis on conservation of areas with large and spectacular ungulate and carnivore species. Some of those areas with the greatest biotic diversity and most complex ecological processes were the most poorly conserved.

Following on from the work of Huntley and Ellis (1983), and also from the earlier work of Lamprey (1975) and others, IUCN is working on a systems plan for the Afrotropical region based on a wide range of published and unpublished work including the Unesco/AETFAT/UNSO vegetation map of Africa (White, 1983), and the Afrotropical Directory prepared by CMC and CNPPA (IUCN, in press).

Similar work is also under way in both the Indomalayan and Oceania regions. The methods and intentions are described more fully by MacKinnon (1985), and have been summarised for OTA by Thorsell (1985b). Similar activities are under way in the Neotropical region.

Other biogeographic considerations

There are a number of 'kinds' of ecosystem that do not fall easily within the types of biogeographical system described so far at the international level, these are ecosystems such as wetlands and coral reefs, and to a certain degree mountains and oceanic islands. In each case the ecosystem concerned forms a sort of mosaic of 'islands' superimposed onto other biogeographic considerations, and is thereby azonal.

The approach to studying the protection of these systems therefore has to be correspondingly different. The method used most frequently is the listing and studying of all potentially important sites, followed by analysis of what is protected, and what needs protection. A good example of this approach would be the lists of important wetland sites drawn up by a number of countries (often at least partially as a result of the efforts under the Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention)).

Few studies of this kind have been carried out at an international level (though there are notable exceptions over certain regions). However, over the last year or two attempts have been made to carry out this type of survey for several major ecosystem types including wetlands, coral reefs and oceanic islands. In essence the approach has been to collect information on all sites of international importance in each ecosystem type, but as the exact approach varies these initiatives are described separately.

Collection of information on coral reefs has been directly coordinated by CMC, working with the IUCN Commission on Ecology. This has involved collection of information on all reefs protected within national parks and reserves, all those proposed for protection, and all those recommended by qualified experts as requiring protection or management on the basis of their scientific interest or economic importance. Much of the information made available so far is compiled as the First Version of the IUCN Directory of Coral Reefs of International Importance (three volumes each of about 500 pages) prepared for the 5th International Coral Reef Congress in Tahiti, May 1985.

Collection of information on wetlands of international importance has continued for a number of years under projects partially or wholly supported by IUCN, the International Wildfowl Research Bureau (IWRB), the International Council for Bird Preservation (ICBP), and UNEP. U.S. Federal agencies and NGOs have also been involved in funding some of the work in south and central America and the Caribbean. In this case, definition of a wetland of international importance is essentially based on the 'Heiligenhafen' criteria as modified by the first conference of contracting parties to the Convention on Wetlands of International Importance Especially as Waterfowl Habitat, Cagliari, 1980 (IWRB, 1980).

So far, information on wetlands of international importance has been collected and published for the Western Palaearctic (Carp, 1980; Scott, 1980), and for all sites listed under the Wetlands Convention (IUCN, 1983). The initial collection of information is completed for the neotropics and is now with IUCN for publication (Scott and Carbonell, in press). Work is also under way for Africa, assisted by the availability of much limnological information collected by SCOPE which is also due to be published next year (Burgis and Symoens, in press). Work will begin shortly on the Indomalayan region, building on work already being done by ICBP, the Interwader project and others.

Oceanic islands are an 'ecosystem group' for which information is widely scattered, even within a single region (e.g. Dahl, 1980), and where there are many particularly urgent problems. There is a therefore a real need to reestablish the database initiatives of the International Biological Programme (Douglas, 1969; Nicholson and Douglas, 1970). ICBP have already carried out the pilot project for an oceanic islands database (jointly planned with the IUCN Conservation Monitoring Centre), and therefore with the earlier IBP work much of the necessary groundwork has been done. IUCN and ICBP are actively seeking funding for the extension of this work to establish a fully developed database.

Concommitant with these database developments is the need for IUCN to develop computer software to help in handling the information. This is discussed further below, and again IUCN are actively seeking funding to carry out this work. This is particularly important, as in all cases the information derived from the above projects, when linked with other information available to CMC, can be used to assess the current conservation situation in each of the different ecosystems types, not only in terms of what is protected and what is not, but in terms of values, threats and so on. This type of database approach is clearly applicable to any discrete habitat type, and is an important development area for CMC.

USE OF THE INFORMATION

Assuming that the information is available, improvement in the use of the available information on status and trends of the in situ conservation of ecosystems depends on two groups of people: those who manage the information, and those who use it. At the international level, and in the case of IUCN the information on protected areas is managed by CMC's Protected Areas Data Unit, but it is used by several other groups, in particular IUCN's Commission on National Parks and Protected Areas (CNPPA).

CNPPA carries out and fosters a wide range of activities for IUCN including development of international priorities for management, focussing of public attention on protected area issues, training, development of publications, support for regional expert meetings, provision of advice to international protected area programmes, and so on. The Commission's activities are largely spelled out in detail in the Bali Action Plan (Miller, 1984), and have been further described for OTA by Thorsell (1985b). As has been noted earlier there is close contact between CNPPA and PADU, with joint work including the use of global biogeography to identify areas where there is inadequate protected areas coverage, and the development of publications which help to identify priorities and to publicise what is being done. Information on specific sites or groups of sites is also of value to CNPPA in making evaluations of world heritage nominations, and was used in 1984 in preparing a presentation on the world's most threatened protected areas.

However, it will be apparent, and has been indicated above, that information on protected areas has much wider application than in the further management and development of protected area systems. Such areas also have a key role to play in wider land-use management and planning, a role that is implicit in much of the work of IUCN and others on protected areas, and which was a central theme in the World National Parks Congress held in Bali, Indonesia, in 1982 (McNeely and Miller, 1984). This role is discussed in a wide variety of publications already quoted, and the aims are well stated in the Bali Action Plan (Miller, 1984) and Action Plans subsequently developed for Africa (in IUCN, 1983), Indomalaya (in Thorsell, 1985a) and more recently for Oceania.

One international programme of particular relevance to this theme is Unesco's Man and the Biosphere Programme, and in particular MAB Project 8; Biosphere Reserves. In summary, biosphere reserves are areas where there can be long-term in situ conservation of plant and animal genetic resources, together with research on ecosystem management and conservation, monitoring of changes in the biosphere, training of specialists, and environmental education (Batisse, 1985). The aims and achievements of the Biosphere Reserve programme so far were extensively discussed during the First International Biosphere Congress held in Minsk, Byelorussia/USSR, in 1983 (Unesco-UNEP, 1984). The congress derived an Action Plan for Biosphere Reserves which has now been adopted by the International Co-ordinating Council of the MAB Programme (Unesco, 1984). The need for an international database on biosphere reserves to help implement this plan is clear, and was addressed at the congress by Harrison (1984), who also discussed standardisation in research and monitoring. In the same session Gregg (1984) discussed the development of scientific programmes to support the multiple roles of biosphere reserves. Both papers make mention of the plan developed by the US National MAB Committee (1979) for development of a staged programme for monitoring and research in biosphere reserves. Unesco are now working with various groups including the US MAB Committee, the Nature Conservancy and the Smithsonian Institution, as well as IUCN, to develop and implement an information system for biosphere reserves which should considerably enhance their value for in situ conservation of biological diversity.

The Global Environment Monitoring System (GEMS) was set up at UNEP, Nairobi, with the specific aim of coordinating environmental monitoring at the global level in order to standardize data collection techniques and to make quality control, monitoring methods and data accessible (Croze, 1984), in order to be able ultimately to produce information necessary and sufficient for the understanding and management of ecosystems. GEMS, therefore, aims to coordinate and direct existing talent and facilities, making use, for example, of other specialised agencies of the United Nations; the World Health Organisation, the World Meterological Organisation, the Food and Agriculture Organisation, Unesco, and so on. The 'nature conservation' part of this database is provided by the IUCN Conservation Monitoring Centre. To be useful, this central database must also be run on computer, so GEMS has embarked on a two-year pilot project to set up a computerized Global Resource Information Database (GRID).

Because the input is from a far wider range of resources than is currently available to the IUCN database (for example satellite imagery, aerial photographs), once GEMS have the GRID fully implemented this will lead to a far better understanding of the status and trends within each ecosystem. Combined with the information IUCN now has, and the improved information it will have by the time GRID is operational (on protected areas, species of concern, discreet habitats and so on) this will enable information users to be much more effective in their use of information to implement conservation action.

Other key users of environmental information are the major development banks. Where these agencies can be provided relatively quickly with background information on conservation concerns within the region - in terms of protected areas, species, habitats etc. - they may be influenced to modify projects to take this sort of information into account, or to obtain and use this information in project development. This stage does not and cannot replace the use of expert consultants on field missions, but provides the necessary background and advance information necessary in project development and planning. The importance the World Bank attaches to environmental aspects of development projects is discussed by Goodland (1984), who also discusses the role of wildlands management in economic development (Goodland, 1985). Additionally, CMC's recent experience is that the private sector is also interested in having such an information service available.

It is clear therefore that the potential for use of information on the situation, status and trends in ecosystems, and the situation, status and trends of in situ conservation in ecosystems, is both wide-ranging and varied, and potentially involves many organisations at the national, regional and international level, as well as governments and individuals.

Because of the wide range of potential users, it would be rather presumptive to suggest how use of the information could be improved, except to say that the better the information and the better the handling of that information, the more effectively it can be used (measures for improvement of the international database which IUCN is already developing are detailed in the next section). What can be stressed however, is the need to:

1. Encourage and support those organisations which use or foster use of environmental data in conservation of ecosystems; and
2. Encourage both wider use of the available information and further research into the land-use, management and planning aspects of the application of that information.

The majority of decisions affecting development and use of natural resources are made at the national or local level, and it should therefore also be noted that there is a specific need to:

3. Encourage the use of a wide range of environmental data in the making of decisions affecting the management and use of natural resources at all levels.

Needless to say, many organizations, government departments, etc., are already working in this area, and what is needed in may case is the additional support and encouragement (both financial and otherwise) to ensure that such activities become an integral and essential part of land-use planning.

Clearly another factor affecting the use of the data available is its accessibility. Information held by the IUCN Conservation Monitoring Centre is, in principle, available to anyone, though the need to both maintain the database and to prepare information for those needing it inevitably leads to the need to make some charge for it. At present we normally respond to written queries from external users offering to provide either packages of basic - largely uninterpreted - data, or by writing reports tailored to a user's requirements. We are however investigating the use of direct access methods with the U.S. National Park Service. It should nevertheless be noted that direct access methods can only provide a 'quick and dirty' answer to any given query at present because information cannot currently be incorporated by CMC as fast as it is being received. This is detailed further below.

These comments will apply to most databases, so even though the networking of information sources is desirable, and probably inevitable, one should never loose sight of the fact that it is unlikely that the computer files will ever contain all the information available to a database, nor is it likely that a computer will ever be able to replace the interpretive ability of an expert familiar with the data. Added to this is the additional problem of different databases using different conventions in the interpretation of their data for codifying it. It should therefore be stressed that

4. Close cooperation between all organisations managing information on conservation issues should be actively encouraged and supported, to ensure good flow of information, avoidance of duplication of effort, and use of similar methods of interpreting data where necessary, with the ultimate aim of improving the use of information.

Possible U.S. response

Recommendations on actions that can/should be taken by various U.S. institutions, development banks, non-governmental groups etc. have been prepared for Congress in two recent documents, the U.S. Strategy on the Conservation of Biological Diversity (an interagency Task Force Report, 1984) and Conserving International Wildlife Resources: The United States Response (a report by The Secretary of State and The Secretary of the Interior, 1984). Within these documents a number of the recommendations clearly relate to the importance of information on the status and trends of ecosystems and their conservation, and directly relate to use of that information. As noted by Thorsell (1985b), IUCN is in general agreement with the thrust of the whole range of recommendations contained within these documents.

Thorsell also recommends a number of actions that could be taken within the United States which would involve use of information directly provided by the IUCN Conservation Monitoring Centre. This includes wider use of the database within the ongoing programmes of USAID, the State Department, and the Department of the Interior. It is also suggested that all U.S. missions abroad should hold up-to-date information on conservation issues within the countries concerned, and that such information could be provided by IUCN/CMC on a subscription basis. As has been noted, IUCN is currently investigating with U.S. National Park Service the possibility of on-line access to protected areas information. Clearly other U.S. organizations may also be interested in using this sort of access, including other federal agencies, the Nature Conservancy and the World Wildlife Fund.

However, perhaps the most important point to make here is that if the United States agencies, institutions etc. encourage and support the use of environmental data in decision making, and use such data in their own decision making processes, this should in itself encourage the development of the information base at all levels. This information base will then provide an improved tool both for making new planning decisions, and reviewing the effects of previous decisions. Further development of the use of information within the U.S. will hopefully also lead to further use of environmental information within planning and managment in other parts of the world.

IMPROVING THE DATABASE

Within the protected areas database now run by IUCN we already have an international database which we believe to be of some value, and which was recognised by the World National Parks Congress as being a valuable tool in the implementation of the Bali Declaration (Recommendation 1, World National Parks Congress, 1984).

The IUCN Conservation Monitoring Centre is also recognised by Conserving International Wildlife Resources: The United States Response (a report by The Secretary of State and The Secretary of the Interior, 1984) as the "principal focal point for information on the status of plants and animals, existing parks and protected areas". Recommendation 2.1 of that report, which emphasisies the value of collecting "in one world repository, sources of information concerning conservation status of species and habitat" also notes that CMC has already made "important strides in this regard and, because of sovereignty sensitivities, would be more likely to receive information freely from all countries" than a similar database in Washington.

This being the case, it is worthwhile discussing further here a number of requirements/shortcomings in the existing database which are apparent to us. Many of these points could equally apply to other databases at local, national and regional levels, and several of the recommendations at the end of the section also apply to these databases. Other recommendations relate to the actual groudwork necessary for the collection of information, which is not discussed in much detail here (it is presumably covered by other papers solicited by OTA).

Assuming that the aims and objectives of the database are clear, there remain three main parts to its development and maintenance:

a) continual collection, verification and compilation of information on protected areas;
b) the management of that information; and
c) use of that information.

The last item has already been discussed.

Collection, verification and compilation of information on protected areas

As was emphasised earlier, good flow of information to an international database ultimately depends on the availability of information within each country; ideally with good information flow from each area to the national level, and from here on to the international database. At each level this information is of value when stored within a database of some form (not necessarily a computer database). Decisions are generally made at the local or national level, therefore within a specific area that information is of value in the management of that site (and of similar sites elsewhere), while at the national level the information is of value in assessment, management and planning within the national system. It is clear that not only must these databases exist, but the wherewithal must be provided for them to interrelate with each other, and with the international database.

In some countries information flow is currently good, in others it is not. It therefore follows that the flow of information to the international level is itself rather variable. The information that comes to CMC also comes from a variety of different sources, from the management authorities, from NGOs, from individual scientists, and so on. In other words, the process of information collection is rather labour intensive, since information must be compared and often verified before the work of incorporating it into either data files or protected area information sheets begins. As a result of this and low staff numbers (PADU is currently limited to a staff of four) this becomes rather a slower process within the IUCN database than is desirable.

In many cases it is also necessary to review the relevant literature on parks and reserves, and to have it to hand for further information, verification of facts, etc. Much of this literature is available in libraries, but it would be sensible in the future to ensure receipt of many more unpublished reports, and other papers and publications direct from the protected areas authorities, international organisations and others responsible. IUCN's Conservation Monitoring Centre does not currently have any set budget for purchase of relevant publications, but this clearly needs to be a future budgetary item.

As well as the national databases mentioned above, a number of regional databases, or 'specialist' databases also exist with which it is important to interrelate. Currently, interrelationship is often hampered by the lack of available funds for the necessary travel to make effective contact between those responsible for organisation of these databases. This is unfortunate not only because of the resulting lower level of interaction, but also as it may result in several international groups approaching a country for essentially similar information.

Within the IUCN Conservation Monitoring Centre we are currently in the process of reviewing data collection procedures on protected areas and are already implementing some improvements. These procedures will also be an item for discussion by a working group set up by IUCN's Commission on National Parks and Protected Areas to look into data collection, management and dissemination. It is intended that this working group will be an advisory body for the IUCN Conservation Monitoring Centre's work on protected areas.

The above would suggest that some of the key actions needed to ensure that good information is available at the international level are to:

1. Strengthen and encourage national and local conservation database development;
2. Foster the free exchange of information and maintain its flow from the local to the national and on to the international level (including support for regional meetings such as those organized by IUCN's Commission on National Parks and Protected Areas);

3. Encourage closer ties between the various regional and international databases dealing with conservation issues; and
4. Strengthen existing database capability of IUCN with the provision of more staff time to improve the capacity to collect and compile information on protected areas, and the provision of proper library facilities.

It should finally be noted here, that the current limiting factor on collection (and management) of information on protected areas by the IUCN Conservation Monitoring Centre remains inadequate staffing levels. There is urgent need for at least two further senior research staff and appropriate support.

As has been mentioned above, the development of national and/or regional conservation databases is a logical step for a variety of reasons, and many are being, or have been, set up in many countries (note for example the work of the U.S. Nature Conservancy in this regard). IUCN's experience in development of its conservation database could be put to good use in assisting in this national/regional development. It is also worth noting that there is still a general lack of use of computers in management of conservation information.

IUCN's Computer Service Unit (within the Conservation Monitoring Centre) has the capability but not the opportunity to develop a standard software package which could be used on micro-computers for establishment of national databases. Apart from the obvious advantage of the simplicity of being able to get a system 'off the shelf' (once the software has been developed) this would also mean that the information would be stored within these databases in a form which could be readily understood within IUCN's computers. It would be likely that CMC would cooperate closely with the U.S Nature Conservancy (International Programme) in this sort of activity.

Management of information

Geographical Information System: Clearly to be of maximum benefit in the analysis of the status and trends of in situ conservation of biological diversity, all of the information available on protected areas must be tied as closely as possible (preferably within the computer database) with information on species and ecosystems, so that comparisons and analyses can be readily carried out. Various 'classification' systems exist which can be used in the assessment of the protected area coverage of various ecosystems. These can be divided into two forms, those that are map based and those that are not.

Mention has already been made of the maps and methodologies of Udvardy (1975), Bailey (1983) and Hayden et al (1984). Other major regional maps which may be important in this sort of analysis are, for example, those for the ecoregions of the United States (Bailey, 1976) and North America (Bailey and Cushwa, 1981), the physical geographical regions of the Nordic countries (Nordic Council of Ministers, 1983), the physical geographical regions of the Soviet Union (Gvozdetskiy, 1968), and so on.

Clearly IUCN needs the capability to handle maps so that information within their database can be quickly located on any part of any map. The ideal solution, and the best long term solution, is the availability of computer hardware and software to handle the maps and their information content, and the necessary support staff to assist in their use. Once this software and hardware is available, in theory any map can be input (including vegetation maps, species distribution maps, distribution of remaining 'virgin' forest, geological maps, soils maps, climatic maps, etc.), and analysis can then be made of protected area coverage using any combination of maps required.

It is also of value to consider information on non-biological or geographical aspects such as distribution of the human population, relative effect of man on different regimes, desertification, estimated productivity, etc. in analysis of in situ conservation. Much of this information can be input as maps, and therefore could be easily handled with full Geographical Information Systems (GIS) capability.

An improved Geographical Information System (GIS) will also bring a series of other benefits. It will make it much easier to relate one area to another, making the database more able to indicate where areas meet, overlap or fall one within another. For example, when asked for a list of conservation areas over 1 million hectares it will not only provide a list of those over this figure, but also a list of sites where their contiguity to other sites takes them over this figure. It will similarly simplify analysis of 'percentage cover' of any given geographical region.

Such a system would also enable us to determine where within a given area another smaller area lies. That this capability is important can be demonstrated by two simple examples. Firstly, it will be able to tell us very quickly which protected areas are on international borders, or the coast and so on. Secondly it will enable IUCN to identify not only which areas are within which biogeographical regions, but which are near the boundaries of those regions. As Pielou (1979) pointed out the areas where transitions occur are important in their own right and deserve special attention.

Another valuable corollary of the development and use of a full GIS would be the capability of relating the information on the size of an area with that on its relative isolation from other protected area, and perhaps also its shape. This should allow further detailed assessment of reserve networks and their efficiency, especially when combined with further information on the effectiveness of management, and eventually on species and species numbers/trends.

Habitats: It is clear that all information within a database must not only be linked to all geographical information based on maps, but on actual ground features. We need to know for example which protected areas actually contain tropical rain forest, elfin forest or mangroves, which contain sea grass beds, glaciers or limestone karst topography and so on. It therefore follows that information on each protected area needs to be linked with a 'habitat' classification system or with numerous partial systems such as vegetation systems (e.g. IUCN, 1973; Unesco, 1973), geomorphological systems, island systems (e.g. Dahl, 1980), wetland systems (e.g. Cowardin et al, 1975) etc. Information on each protected area is very variable, as we have noted, so classifications clearly need to be hierarchical so that information can be used, however crude or sophisticated. It has been suggested that a single system should be developed which will be used not only by IUCN for management of its information on protected areas and species, but also by the GRID.

Once such a scheme is available, this will form a major 'skeleton' throughout the CMC database, with both protected areas and species linked to the habitat types which they contain, or are found associated with, respectively. Implementation will be a very time consuming task, however, and one for which outside funding will be required.

Ecosystem inventories: As was noted earlier, IUCN has also been involved in projects concerning management of information on specific ecosystem types such as coral reefs, wetlands and oceanic islands. Work like this clearly needs to be improved and extended so that information on ecosystems of concern can be more effectively collected and managed, and linked with information on both the species and protected areas in those ecosystems. Only in this way can full assessment of the conservation status of these particular systems be made, and only when much of this information is together can recommendations and advice be given to conservation and development agencies and other interested groups.

Species inventories: One of the principal justifications given for the establishment and maintenance of protected areas is the conservation of genetic resources in situ. Therefore, it is of vital importance that information on what is found where is available to those needing it. The amount of information available at the local level is growing, and with the increasing availability of improved information handling methods it would seem likely that local and national database activity on the location of genetic resources will increase.

It is obvious, however, that an international database maintaining links with local, national and regional database activity is essential. The role of such a database would be to provide an overview; to demonstrate what is found where (i.e. an information retrieval service); to highlight resources that do not appear to be protected; and to draw the attention of management authorities to the relative importance of some of the species they protect (important resources that may not be protected elsewhere, for example).

CMC already has growing databases on both species and protected areas, while other groups such as Unesco (MAB programme), FAO and IBPGR are also exploring this type of database activity for either particular species groups or particular areas. Unesco (MAB), for example, are interested in developing a much more detailed information system for biosphere reserves. The U.S. National Committee for MAB have just funded an initial project between the Smithsonian Institution, the U.S. Nature Conservancy and the U.S. National Park Service to look at methodologies for developing and storing information on biosphere reserves (including the status of plant and animal taxa). A pilot testing of the methodologies will be carried out in selected biosphere reserves in China, Mexico and the U.S.A., but the system will be extended in time to cover all biosphere reserves. The IUCN Conservation Monitoring Centre will be involved in this project, and it is intended that CMC become an integral part of the international database on biosphere reserves.

IUCN already has on file large amounts of information on species of conservation concern (threatened species, economic plants/animals and other 'genetic resources', etc.). The most visible part of this database is the well known Red Data Book series (Lucas and Synge, 1978; Thornback and Jenkins, 1982; Groombridge, 1982; Wells et al, 1983; Collar and Stuart, 1985; Collins and Morris, 1985). However, to be able to establish to what degree particular species are actually represented in protected areas requires both a large increase in the amount of information collected and maintained by CMC, and the full linking of the information on protected areas and species within the computer.

In many cases, however, this information may not actually exist yet - especially when information on species population size, status and trends are required. Also, the amount of information that could be included is infinite, and the process must therefore be restricted. However, no full assessment has yet been made on what species it would be valuable for such a database to include (though some work on this has been done for plant species), or from what types of areas. It is therefore necessary initially to carry out a study of what information is required for what species and from what areas, followed by an implementation stage which would involve a computer programming component, as well as the information collection and management. This work would be carried out in close collaboration with other international groups and agencies working in this field.

It should be noted, however, that establishment of a full species-area database would be a long term, labour intensive programme of work at all levels, from the information collectors, to local databases, and right through to the international level. Speeding up the process would require better information at the 'field' level, improved database activity, and improved coordination. IUCN, in cooperation with others, can assist in ensuring improved coordination, but perhaps of as much value would be the development by the IUCN Conservation Monitoring Centre of database software which could be used not only within CMC's database, but at all levels - thus ensuring increased compatability.

Effectiveness of management: It was noted above that IUCN's application of the system of management categories also currently attempts to take into account elements of management effectiveness rather than just management objectives. It would seem sensible to actually look at these issues separately, and IUCN's Commission on National Parks and Protected Areas are working on a questionnaire which can be used to evaluate the effectiveness of an area in achieving its management objectives. Wide use of such a questionnaire should lead to a better understanding of how effective the conservation effort is within different ecosystems. Again, as with most of these improvements in available information, implementation will be a time intensive process at all levels.

Additional key actions needed to ensure good management of information at the international level are therefore to:

5. Strengthen existing database capability of IUCN with the provision of a full GIS, the hardware to run it on, and the support staff to implement it.
6. Support the development of a comprehensive 'habitat information' classification, and once developed, support its implementation by international databases, and where relevant by national and regional databases.
7. Encourage application of improved methods to assess the achievement of management objectives for use at all database levels.

Also, to answer the full series of relevant questions on in situ conservation of ecosystems all this information relies on the available information on species and ecosystems. It is therefore necessary to:

8. Strengthen the existing database capability of IUCN to improve the capacity to collect and compile information on species of conservation concern, and ecosystems, and to link it more fully with information on protected areas.

Implicit in all of this discussion is that the information is of value at all levels - not just internationally, and therefore there is a need as recommended above to:

9. Encourage the development of national and local databases managing information for use in decision making and planning at those levels.

What must also be apparent, however, is the need for large amounts of information on species and habitat distribution. The more accurate and complete the records are, the more objective the biogeographical analyses can be, and hence the better the proposals/judgements made based on these analyses. This information depends on two factors, collection/identification, and coordination of information. There is therefore a need to:

10. Encourage and support the necessary basic research requiring systematists (to classify the species in the first place), fieldworkers and other scientists to identify and locate items of the biota (including habitats), and biogeographers and other scientists to analyse the available information);

and to:

11. Encourage the development of effective cross-linking/networking of databases maintaining information on species/habitat, location/distribution.

Clearly both of these activities are at the very core of information work in conservation, and involve a wide body of people from a wide range of organizations. In particular one should note the role of museums and universities, as well as government offices such as parks and wildlife departments. The funding sources for these activities are similarly diverse.

Possible U.S. response

As was mentioned in the previous section, recommendations on actions that can/should be taken by various U.S. institutions, development banks, non-governmental groups etc. have been prepared for Congress in two recent documents, the U.S. Strategy on the Conservation of Biological Diversity (an interagency Task Force Report, 1984) and Conserving International Wildlife Resources: The United States Response (a report by The Secretary of State and The Secretary of the Interior, 1984). Many of the recommendations of these reports, if carried out, will lead to great improvement in the available information, and hopefully an improvement in information flow to the IUCN Conservation Monitoring Centre, and an improvement in information quality.

Clearly, however, CMC needs further resources to carry out these tasks. Direct core funding is perhaps the most obvious aspect of this requirement, and the most useful, but there are others. The possible input that could be made by U.S. agencies is therefore:

1. Contribution of additional core funding;
2. Payment of subscription fees to CMC for provision of information on a number of agreed topics over a given period of time;
3. Provision of funding for specific projects where CMC provides information to U.S. agencies;
4. Placement of U.S. personnel to work with the IUCN Conservation Monitoring Centre for given periods of time on specific agreed projects (or financial support for the same post).

In addition U.S. agencies should take an active role in development of the whole information network through:

5. Providing encouragement and support for those organisations actively involved in the development of such databases.
6. Providing support for international meetings of experts which foster the exchange of information.
7. Encourage and support the basic research necessary to provide much of the required background information.

This last point is a major one, and could in itself take up a whole paper.

SUMMARY

The following recommendations have been made in the preceeding discussion, but have been rearranged here in order to clarify their meaning when stated without the accompanying text. Several dealing with similar issues have been amalgamated.

Recommendations relating to the availability of information

1. Encourage and support the necessary basic research, requiring systematists (to classify the species in the first place), fieldworkers and other scientists to identify and locate items of the biota (including habitats), and biogeographers and other scientists to analyse available information.

2. Encourage and support the development of effective cross-linking and networking of all databases maintaining information on species/habitat locations/distributions.

Recommendations relating to national and local conservation databases

1. Encourage and support national and local conservation database development.

2. Encourage the use of a wide range of environmental data in the making of decisions affecting the management and use of natural resources at all levels.

Recommendations relating to improvement of information exchange

1. Foster the free exchange of information and maintain its flow from the local to the national and on to the international level (including support for regional meetings such as those organized by IUCN's Commission on National Parks and Protected Areas);

2. Encourage and support close cooperation between all organisations managing information on conservation issues to ensure good flow of information, avoidance of duplication of effort, and use of similar methods of interpreting data where necessary.

Recommendations relating specifically to IUCN's international database

1. Strengthen existing database capability of IUCN with the provision of more staff time to improve the capacity to collect and compile information on protected areas, and the provision of proper library facilities.

2. Strengthen the existing database capability of IUCN to improve the capacity to collect and compile information on species of conservation concern, and ecosystems, and to link it more fully with information on protected areas.

3. Strengthen existing database capability of IUCN with the provision of a full Geographical Information System, the hardware to run it on, and the support staff to implement it.

4. Support the development of a comprehensive 'habitat information' classification, and once developed, support its implementation by international databases, and where relevant by national and regional databases.

5. Support the development and application of improved methods to assess the achievement of management objectives within protected areas for use at all database levels.

Recommendations relating to use of the information

1. Encourage and support those organisations (at all levels) which use or foster use of environmental data in conservation of ecosystems.

2. Encourage both wider use of the available information and further research into the land-use, management and planning aspects of the application of that information.

However, perhaps the most important point to make in conclusion is that if United States agencies, institutions etc. encourage and support the use of environmental data in decision making, and use such data in their own decision making processes, this should in itself encourage the development of the information base at all levels. This information base will then provide an improved tool both for making new planning decisions, and reviewing the effects of previous decisions. Further development of the use of such information within the U.S. will hopefully also lead to further use of environmental information within planning and management in other parts of the world.

REFERENCES

Bailey, R.G. (1976). *Ecoregions of the United States*. U.S. Forest Service, Department of Agriculture.

Bailey, R.G. (1980). *Description of the ecoregions of the United States*. U.S. Department of Agriculture Miscellaneous Publication 1391, Washington D.C. 77 pp.

Bailey, R.G. (1983). Delineation of ecosystem regions. *Environmental Management* 7: 365-373.

Bailey, R.G. and Cushwa, C.T. (1981). *Ecoregions of North America*. U.S. Fish and Wildlife Service, Department of Interior.

Batisse, M. (1985). The Biosphere Reserve: A tool for Environmental Conservation and Management. *Environmental Conservation* 9(2): 101-111.

Burgis, M.J. and Symoens, J.J. (In press). *African wetlands and shallow water bodies*. Volume 2: Directory. ORSTOM, Paris.

Carp, E. (1980). *A Directory of Western Palaearctic Wetlands*. IUCN, Gland.

Clark and Dingwall (1985). *Conservation of islands in the Southern Ocean*. IUCN, Gland.

Collar, N.J. and Stuart, S.N. (1985). *Threatened Birds of Africa and Related Islands: The ICBP/IUCN Red Data Book*. ICBP/IUCN, Cambridge, United Kingdom.

Collins, N.M. and Morris, M.G. (1985). *Treatened Swallowtail Butterflies of the World: The IUCN Red Data Book*. IUCN, Gland, Switzerland and Cambridge, United Kingdom.

Cowardin, L.M., Carter, V., Golet, F.C., LaRoe, E.T. (1975). Classification of Wetlands and Deepwater Habitats of the United States. Fish and Wildlife Service, U.S. Department of the Interior.

Crowley, J.M. (1967). Biogeography. *Canadian Geographical* 11: 312-326.

Croze, H. (1984). Global Monitoring and Biosphere Reserves. In: Unesco-UNEP (loc cit).

Dahl, A.L. (1980). Regional Ecosystem Survey of the South Pacific Area. South Pacific Commission, Noumea, New Caledonia.

Dasmann, R.F. (1973). A system for defining and classifying natural regions for purposes of conservation. IUCN Occasional paper No. 7.

Department of Lands and Survey (1984). Register of protected natural areas in New Zealand. Wellington, N.Z.

Dice, L.R. (1943). *The Biotic Provinces of North America*. University of Michigan Press, Ann Arbor.

Douglas, G. (1969). Check List of Pacific Oceanic Islands. Micronesica 5(2): 327-463. Reprinted by the International Biological Programme/Conservation Section.

Frankel, O.H. and Soulé, M.E. (1981). Conservation and Evolution. Cambridge Unbiversity Press, Cambridge, United Kingdom.

Goodland, R. (1984). The World Bank, Environment, and Protected Areas. In: McNeely and Miller (loc cit).

Goodland, R. (1985). Wildlands Management in Economic Development. Paper presented to the First International Wildlife Symposium, IX World Forestry Congress, Mexico, May 1985.

Gregg, W. (1984). Building science programmes to support the multiple roles of biosphere reserves. In: Unesco-UNEP (loc cit).

Groombridge, B. (1982). The IUCN Amphibia-Reptilia Red Data Book. IUCN, Gland, Switzerland.

Gvozdetskiy, N.A. (1968). Nekotoriye obshchiye teoreticheskiye i metodicheskiye voprosy fiziko-geograficheskogoe rayonirovaniya. In: Fiziko-geograficheskoye rayonirovaniye SSSR. Nauka, Moscow.

Harrison, J (1984). An international data bank on biosphere reserves and the need for standardization. In: Unesco-UNEP (loc cit).

Harrison, J., Miller, K. and McNeely, J (1982). The World Coverage of Protected Areas: Development Goals and Environmental Needs. Ambio 11(5): 238-245.

Hayden, B.P., Ray, G.C., Dolan, R. (1984). Classification of Coastal and Marine Environments. Environmental Conservation 11(3): 199-207.

Huntley, B.J. and Ellis, S. (1983). Conservation Status of Terrestrial Ecosystems in Southern Africa. Unpublished paper prepared for IUCN.

IBDF (1982). Plano do sistema de unidades de conservacao do Brasil. Instituto Brasileiro de Desenvolvimento Florestal, Ministerio da Agricultura.

IUCN (1973). A Working System for Classification of World Vegetation. IUCN Occasional Paper No. 5, IUCN, Morges, Switzerland.

IUCN (1974). Biotic Provinces of the World. IUCN Occasional paper No. 9.

IUCN (1978). Categories, objectives and criteria for protected areas IUCN, Morges, Switzerland. 26 pp.

IUCN (1980). World Conservation Strategy. IUCN, Gland.

IUCN (1983). Draft Directory of Wetlands of International Importance. IUCN, Cambridge, United Kingdom.

IUCN (1983). Proceedings of the Twenty-second working session, Commission on National Parks and Protected Areas, Victoria Falls, Zimbabwe. IUCN, Switzerland.

IUCN (1984). Categories, objectives and criteria for protected areas. In: McNeely and Miller (loc cit).

IUCN (1985). The United Nations List of National Parks and Protected Areas. IUCN, Gland and Cambridge.

IUCN (In press). The IUCN Directory of Afrotropical Protected Areas. IUCN, Cambridge, United Kingdom.

IWRB (1980). Conference on the Conservation of Wetlands of International Importance Especially as Waterfowl Habitat, Cagliari, Italy. IWRB, Slimbridge, United Kingdom.

Köppen, W. (1931). Grundriss der Klimakunde. Walter de Gruyter Co., Berlin. 388 pp.

Lamprey, H.F. (1975). The distribution of protected areas in relation to the needs of biotic community conservation in Eastern Africa. IUCN Occasional Paper No. 16.

Lovejoy, T., Bierregaard, R.O., Rankin, J. and Schubart, H.O.R. (1983). Tropical Rain Forest: Ecology and Management. Special Publication Number 2 of the British Ecological Society. Blackwell Scientific Publications, Oxford.

Lucas, G, and Synge, H. (1978). The IUCN Plant Red Data Book. IUCN, Morges, Switzerland.

MacKinnon, J. (1985). Outline of a methodology for preparation of a "Review of the Protected Areas System of the Indomalayan Realm". In: Thorsell (1985a).

McNeely, J.A. and Miller, K.R. (1984). National Parks, Conservation, and Development: The role of Protected Areas in Sustaining Society. Proceedings of the World Congress on National Parks, Bali, Indonesia. Smithsonian Institution Press, Washington, D.C.

Miller, K.R. (1984). The Bali Action Plan: A Framework for the Future of Protected Areas. In: McNeely and Miller (loc cit).

Nicholson, E.M. and Douglas, G.L. (1970). Conservation of Oceanic Islands. In: Elliott, H.F.I. (Ed.) IUCN Eleventh Technical Meeting. IUCN Publications New Series No. 17. IUCN, Morges.

Nordic Council of Ministers (1983). Physical-geographical regions. Nordic Council of Ministers.

Oldfield, M.L. (1984). The value of conserving Genetic Resources. National Park Service, United States Department of the Interior.

Pielou, E.C. (1979). Biogeography. Wiley Interscience, New York, U.S.A.

Prance, G. (1977). Extinction is Forever. New York Botanic Garden, New York.

Rodgers, W.A. (1985). Biogeography and protected area planning in India. In: Thorsell (1985a).

Schonewald-Cox, C.M., Chambers, S.M., Macbryde, B. and Thomas, W.L. (eds.)(1983). Genetics and Conservation: A reference for managing wild animal and plant populations. The Benjamin cummings Publishing Company, California.

Scott, D.A. (1980). A preliminary inventory of Wetlands of International Importance for Waterfowl in West Europe and Northwest Africa. IWRB Special Publication No. 2. IWRB, Slimbridge, United Kingdom.

Scott, D.A. and Carbonell, M. (In press). A Directory of Neotropical Wetlands. IUCN, Gland and Cambridge.

Soulé, M.E. (1984). Applications of genetics and population biology: The what, where and how of nature reserves. In: Unesco-UNEP (loc cit).

Soulé, M.E. and Wilcox, B.A. (Eds)(1980). Conservation Biology: An Evolutionary-Ecological Perspective. Sinauer Associates, Sunderland, Massachusetts.

Terborgh, J. and Winter, B. (1983). A Method for Siting Parks and Reserves with Special Reference to Colombia and Ecuador. Biological Conservation 27(1): 45-58.

Thornback, J. and Jenkins, M. (1982). The IUCN Mammal Red Data Book. IUCN, Gland, Switzerland.

Thorsell, J. (ed.)(1985a). Conserving Asia's Natural Heritage: Proceedings of the twenty-fifth working session of CNPPA. IUCN, Gland.

Thorsell, J. (1985b). The Role of Protected Areas in Maintaining Biological Diversity in Tropical Developing Countries. A paper prepared for the Office of Technology Assessment, Congress of the United States.

U.S. National MAB Committee (1979). Long term ecological monitoring in biosphere reserves. Washington, DC.

Udvardy, M.D.F. (1975). A classification of the Biogeographical Provinces of the World. IUCN Occasional Paper No. 18.

Unesco (1973). Classification and Mapping of Vegetation on a World Basis. Unesco paper SC/WS/269, Paris.

Unesco (1984). Action Plan for Biosphere Reserves. Nature and Resources XX(4): 1-12.

Unesco-UNEP (1984). Conservation, Science and Society. Contributions to the First International Biosphere Reserve Congress, Minsk, Byelorussia/USSR. Unesco, Paris.

Wells, S.M., Pyle, R.M. and Collins, N.M. (1983). The IUCN Invertebrate Red Data Book. IUCN, Gland, Switzerland.

Wetterberg, G.B., Jorge Padua, M.T., Bernardes Quintao, A.T. and Ponce del Prado, C.F. (1985). Decade of Progress for South American National Parks. National Park Service, United States Department of the Interior.

Wetterberg, G.B., Prance, G.T. and Lovejoy, T.E. (1981). Conservation progress in Amazonia: A structural Review. Parks 6(2): 5-10.

White, F. (1983). The Vegetation of Africa. A descriptive memoir acompanying the Unesco/AETFAT/UNSO vegetation map of Africa. Unesco, Paris.

Wilson, J.L. (1984). Nature conservation reserves in Australia (1984). Occasional paper No. 10. Australian National Parks and Wildlife Service, Canberra.

World National Parks Congress (1984). Recommendation 1: Information on Protected Areas. In: McNeely and Miller (loc cit).

LIST OF ABBREVIATIONS

CMC	IUCN Conservation Monitoring Centre
CNPPA	IUCN Commission on National Parks and Protected Areas
FAO	Food and Agriculture Organization of the United Nations
GEMS	UNEP Global Environment Monitoring System
GIS	Geographical Information System
GRID	GEMS Global Resource Inventory Database
IBP	International Biological Programme
IBPGR	International Board for Plant Genetic Resources
ICBP	International Council for Bird Preservation
IUCN	International Union for Conservation of Nature and Natural Resources
IWRB	International Waterfowl Research Bureau
MAB	Man and the Biosphere (a Unesco programme)
OECD	Organization for Economic Cooperation and Development
PADU	CMC's Protected Areas Data Unit
UNEP	United Nations Environment Programme
Unesco	United Nations Educational, Scientific and Cultural Organization
USNPS	U.S. National Park Service
USFWS	U.S. Fish and Wildlife Service

Table 1: Categories and management objectives of protected areas

I Scientific Reserve/Strict Nature Reserve: To protect nature and maintain natural processes in an undisturbed state in order to have ecologically representative examples of the natural environment available for scientific study, environmental monitoring, education, and for the maintenance of genetic resources in a dynamic and evolutionary state.

II National Park: To protect natural and scenic areas of national or international significance for scientific, educational, and recreational use.

III Natural Monument/Natural Landmark: To protect and preserve nationally significant natural features because of their special interest or unique characteristics.

IV Managed Nature Reserve/Wildlife Sanctuary: To assure the natural conditions necessary to protect nationally significant species, groups of species, biotic communities, or physical features of the environment where these require specific human manipulation for their perpetuation.

V Protected Landscape or seascape: To maintain nationally significant natural landscapes which are characteristic of the harmonious interaction of man and land while providing opportunities for public enjoyment through recreation and tourism within the normal life style and economic activity of these areas.

VI Resource Reserve: To protect the natural resources of the area for future use and prevent or contain development activites that could affect the resource pending the establishment of objectives which are based upon appropriate knowledge and planning.

VII Natural Biotic Area/Anthropological Reserve: To allow the way of life of societies living in harmony with the environment to continue undisturbed by modern technology.

VIII Multiple-Use Management Area/Managed Resource Area: To provide for the sustained production of water, timber, wildlife, pasture, and outdoor recreation, with the conservation of nature primarily oriented to the support of the economic activities (although specific zones may also be designed within these areas to achieve specific conservation objectives).

IX. Biosphere Reserve: To conserve for present and future use the diversity and integrity of representative biotic communities of plants and animals within natural ecosystems, and to safeguard the genetic diversity of species on which their continuing evolution depends.

X. World Heritage Site: To protect the natural features for which the area was considered to be of World Heritage quality, and to provide information for world-wide public enlightenment.

Adapted by Thorsell (1985) from IUCN (1984)

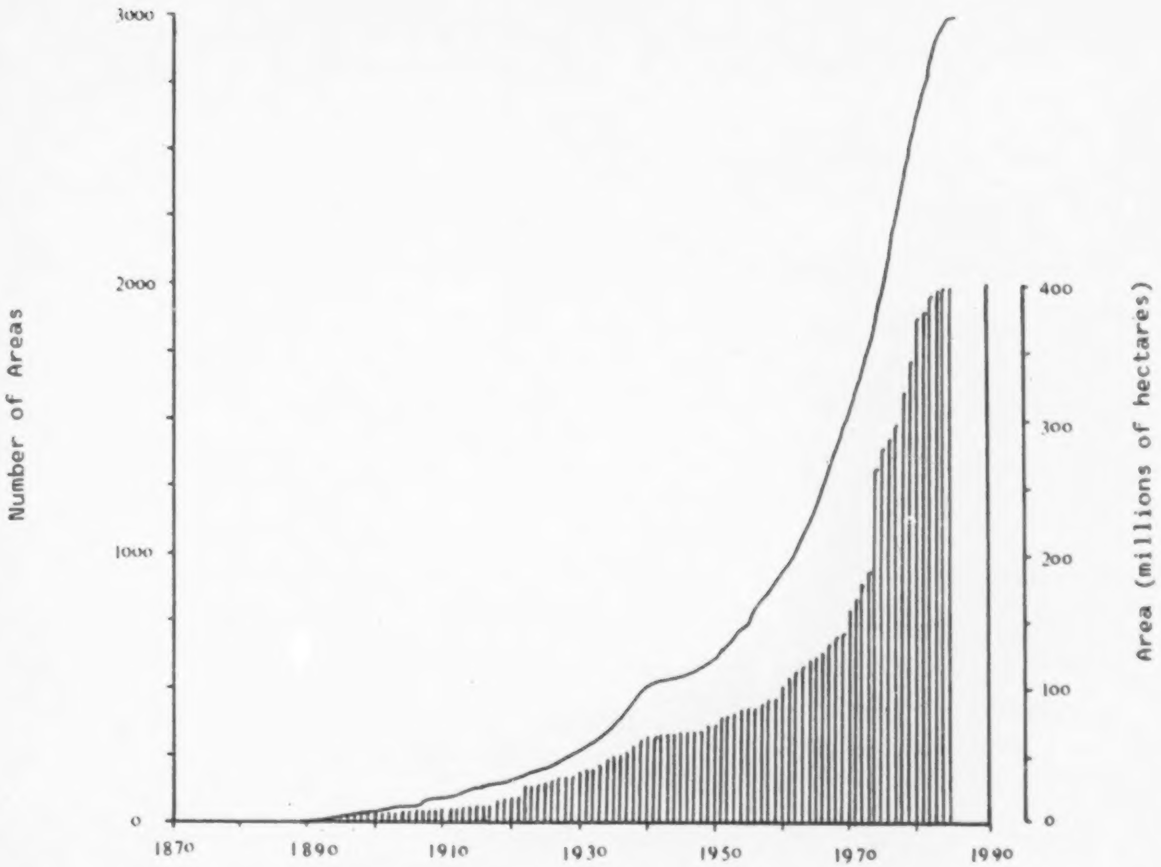


Figure 1 Growth of the world coverage of protected areas. Number of protected areas (———) and total area protected (▥) in IUCN management categories I–V.

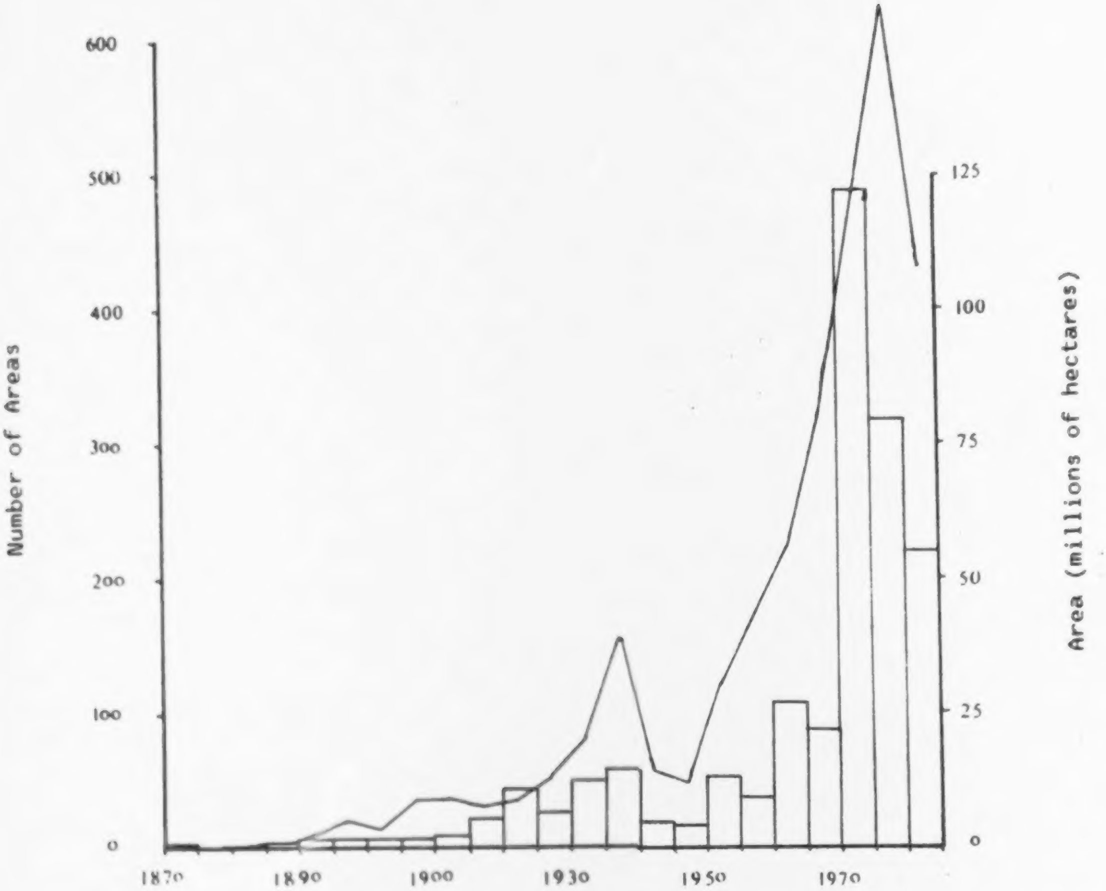
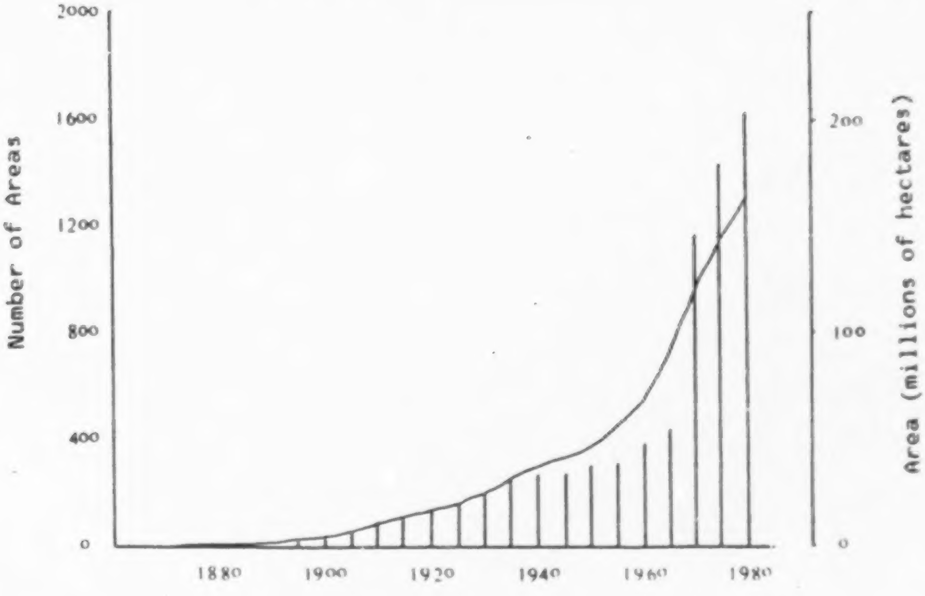


Figure 2 Number of protected areas established (———) and their total area (▭) in each five year period since 1870. IUCN management categories I–V.

OECD countries



Non-OECD countries

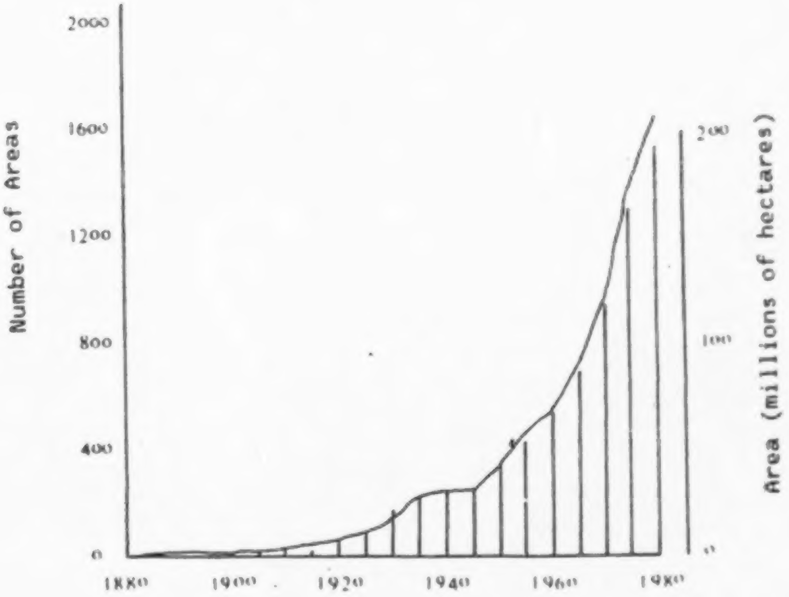


Figure 3 Number of protected areas (———) and total area protected (|||||||) in IUCN management categories I-V broken down by whether the sites are within countries which are members of OECD or not.

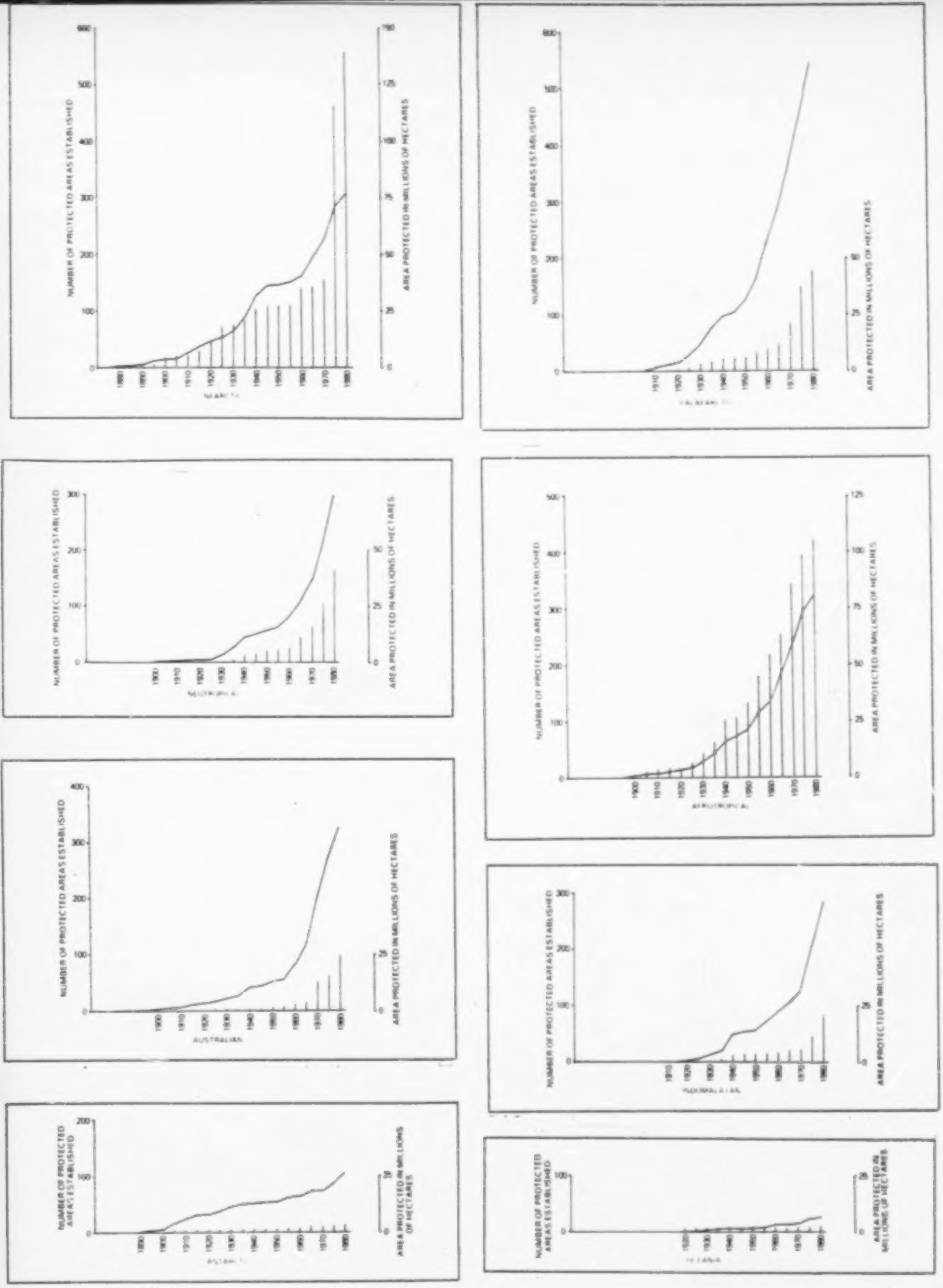


Figure 4 Number of protected areas (———) and total area protected (|||||||||) in IUCN management categories I-V, broken down by biogeographical realm (after Udvardy, 1975).

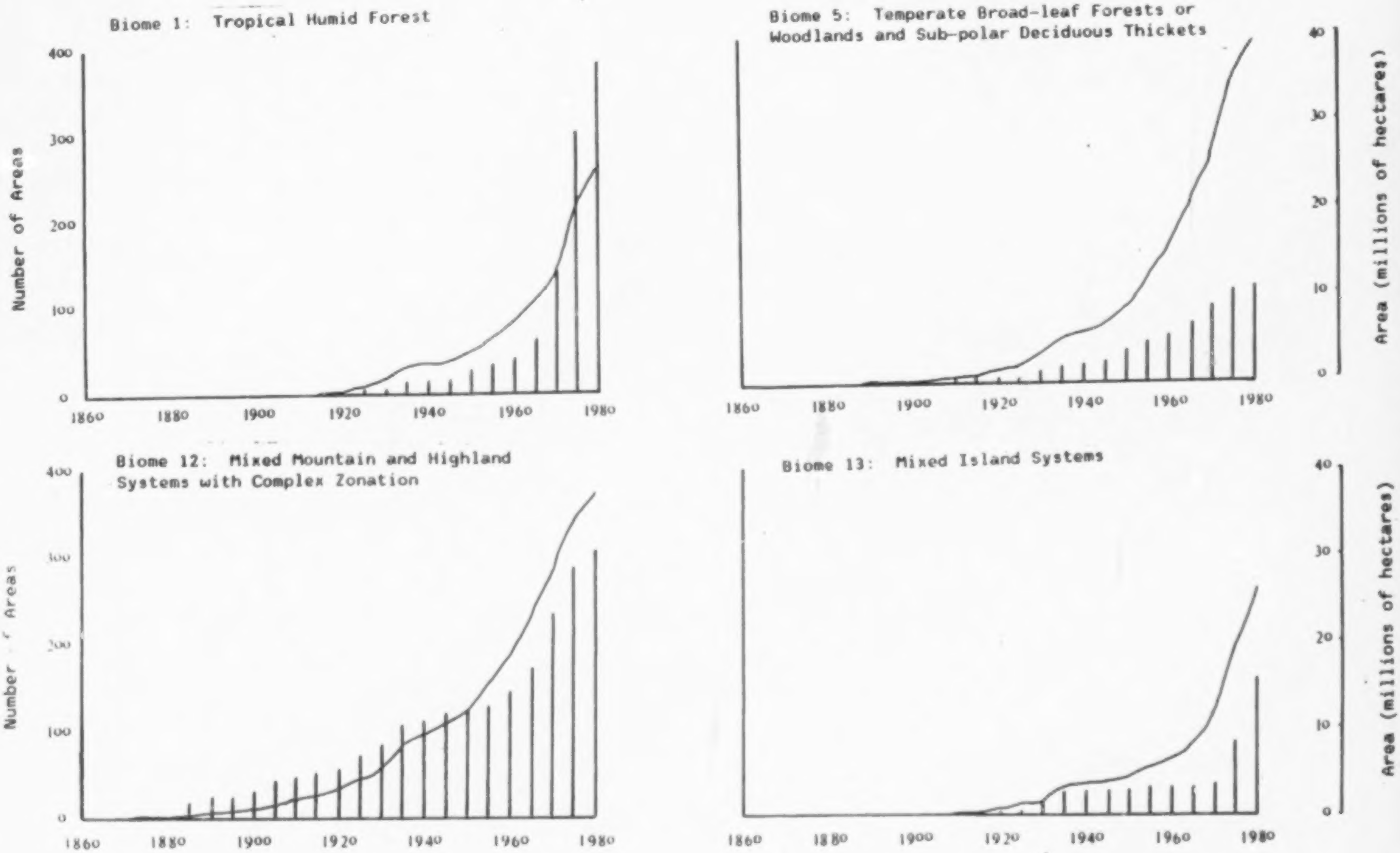


Figure 5 Number of protected areas (———) and total area protected (| | | | |) in IUCN management categories I–V, broken down by biome type (after Udvardy, 1975).

Table 2: Protected areas in South America

Country	Size of country	Population	No of Areas	Total area (hectares)	ha/sqkm (%)	ha protected per 1,000 head
ARGENTINA	2,776,643	26,393,000 (1978)	29	2,594,351	0.93	98.30
BOLIVIA	1,098,575	6,113,000 (1978)	12	4,707,690	4.29	770.11
BRAZIL	8,511,968	115,397,000 (1978)	50	11,894,302	1.40	103.07
CHILE	756,943	10,656,000 (1977)	64	12,737,360	16.83	1,195.32
COLOMBIA	1,138,907	25,048,000 (1977)	30	3,958,750	3.48	158.05
ECUADOR	455,502	7,814,000 (1978)	12	2,627,365	5.77	336.24
FRENCH GUIANA	90,000	59,000 (1977)	0	0		
GUYANA	214,969	819,000 (1978)	1	11,655	0.05	14.23
PERU	1,285,215	16,819,000 (1978)	11	2,407,642	1.87	143.15
PARAGUAY	406,750	2,888,000 (1978)	9	1,120,538	2.75	388.00
SURINAME	163,820	448,000 (1977)	9	582,400	3.56	1,300.00
URUGUAY	186,925	2,864,000 (1978)	6	28,778	0.15	10.05
VENEZUELA	912,047	13,122,000 (1978)	34	7,388,912	8.10	563.09

Total area of South America	17,998,264 sq km
Total population	228,440,000
Total number of protected areas	267
Total area protected	50,059,743 hectares
Percentage protected	2.78 ha protected/sq.km
Comparison with population	219.14 ha/1000 people

Based on IUCN (1985), IUCN Management Categories I-V

Table 3: Analysis by biome type

Biome and Realm	Number of areas	Total area (hectares)
Tropical humid forests		
Afrotropical	44	8,905,733
Indomalayan	122	5,092,774
Australian	53	7,776,347
Neotropical	61	17,277,197
	280	39,052,051
Subtropical/temperate rainforests/woodlands		
Nearctic	18	4,250,171
Palaearctic	48	1,742,994
Australian	26	904,976
Antarctic	145	2,783,281
Neotropical	38	8,848,838
	275	18,530,260
Temperate needle-leaf forests/woodlands		
Nearctic	53	30,321,679
Palaearctic	122	8,463,690
	175	38,785,369
Tropical dry forests/woodlands		
Afrotropical	240	48,673,552
Indomalayan	238	10,420,406
Australian	10	934,272
Neotropical	93	5,501,447
	581	65,529,677
Temperate broad-leaf forests		
Nearctic	82	1,890,216
Palaearctic	400	9,631,346
Neotropical	1	5,415
	483	11,526,977
Evergreen sclerophyllous forests		
Nearctic	6	52,010
Palaearctic	122	3,374,156
Afrotropical	41	1,620,967
Australian	301	6,918,823
Neotropical	5	38,795
	475	12,004,751

Table 3 (cont.): Analysis by biome type

Biome and Realm	Number of areas	Total area (hectares)
Warm deserts/semi-deserts		
Nearctic	22	3,962,948
Palaearctic	7	616,534
Afrotropical	57	23,783,085
Indomalayan	35	1,628,854
Australian	33	10,165,383
Neotropical	7	1,446,751
	161	41,603,555
Cold-winter deserts		
Nearctic	15	657,128
Palaearctic	57	12,854,167
Neotropical	4	36,700
	76	13,547,995
Tundra communities		
Nearctic	20	107,924,951
Palaearctic	8	7,247,904
Antarctic	12	295,034
	40	115,467,889
Tropical grasslands/savannas		
Australian	12	2,041,393
Neotropical	18	7,011,403
	30	9,052,796
Temperate grasslands		
Nearctic	25	387,751
Palaearctic	22	805,408
Australian	34	670,163
Neotropical	9	70,516
	90	1,933,838
Mixed mountain systems		
Nearctic	81	8,321,078
Palaearctic	231	8,071,815
Afrotropical	38	5,104,626
Neotropical	86	11,037,282
	436	32,534,801

Table 3 (cont.): Analysis by biome type

Biome and Realm	Number of areas	Total area (hectares)
Mixed island systems		
Palaearctic	9	52,142
Afrotropical	4	23,033
Indomalayan	177	10,426,372
Oceanian	54	4,127 602
Neotropical	26	1,190,599
	270	15,819,748
Lake systems		
Nearctic	7	444,713
Palaearctic	1	18,300
Afrotropical	2	55,100
Neotropical		
	10	518,113
Biogeographical classification unknown	132	7,866,578
TOTAL	3,514	423,774,398

Table 4: Analysis by biogeographical province

	Name of Province	Number of areas	Total area (hectares)
1 01 02	Sitkan	12	3,869,827
1 02 02	Oregonian	6	380,344
1 03 03	Yukon Taiga	12	21,010,636
1 04 03	Canadian Taiga	41	9,311,043
1 05 05	Eastern Forest	39	1,155,364
1 06 05	Austroriparian	43	734,852
1 07 06	Californian	6	52,010
1 08 07	Sonoran	11	3,464,499
1 09 07	Chihuahuan	10	493,332
1 10 07	Tamaulipan	1	5,117
1 11 08	Great Basin	15	657,128
1 12 09	Aleutian Islands	7	7,025,370
1 13 09	Alaskan Tundra	9	25,292,471
1 14 09	Canadian Tundra	2	4,557,110
1 15 09	Arctic Archipelago		0
1 16 09	Greenland Tundra		0
1 17 09	Arctic Desert and Icecap	2	71,050,000
1 18 11	Grasslands	25	387,751
1 19 12	Rocky Mountains	46	6,783,793
1 20 12	Sierra-Cascade	16	1,251,492
1 21 12	Madrean-Cordilleran	19	285,793
1 22 14	Great Lakes	7	444,713
		329	158,212,645
2 01 02	Chinese Subtropical Forest	10	312,509
2 02 02	Japanese Evergreen Forest	38	1,430,485
2 03 03	West Eurasian Taiga	106	5,061,090
2 04 03	East Siberian Taiga	16	3,402,600
2 05 05	Icelandian	22	791,431
2 06 05	Subarctic Birchwoods	14	258,590
2 07 05	Kamchatkan	1	964,000
2 08 05	British Islands	34	1,463,117
2 09 05	Atlantic	96	1,063,740
2 10 05	Boreonemoral	55	743,047
2 11 05	Middle European Forest	97	1,232,282
2 12 05	Pannonian	22	245,056
2 13 05	West Anatolian	1	11,338
2 14 05	Manchu-Japanese Mixed Forest	22	1,480,074
2 15 05	Oriental Deciduous Forest	36	1,378,671
2 16 06	Iberian Highlands	42	1,835,557
2 17 06	Mediterranean Sclerophyll	80	1,538,599
2 18 07	Sahara	2	117,094
2 19 07	Arabian Desert	5	499,440
2 20 08	Anatolian-Iranian Desert	32	5,499,190
2 21 08	Turanian	13	1,170,858
2 22 08	Takla-Makan-Gobi Desert	2	4,507,850

Table 4 (cont.): Analysis by biogeographical province

	Name of Province	Number of areas	Total area (hectares)
2 23 08	Tibetan	1	266,913
2 24 08	Iranian Desert	9	1,409,356
2 25 09	Arctic Desert	5	3,491,000
2 26 09	Higharctic Tundra	1	795,650
2 27 09	Lowarctic Tundra	2	2,961,254
2 28 11	Atlas Steppe	3	51,775
2 29 11	Pontian Steppe	16	581,053
2 30 11	Mongolian-Manchurian Steppe	3	172,580
2 31 12	Scottish Highlands	20	81,723
2 32 12	Central European Highlands	105	2,037,182
2 33 12	Balkan Highlands	32	390,241
2 34 12	Caucaso-Iranian Highlands	42	2,236,152
2 35 12	Altai Highlands	2	935,093
2 36 12	Pamir-Tian-Shan Highlands	17	616,490
2 37 12	Hindu Kush Highlands	1	14,786
2 38 12	Himalayan Highlands	10	1,708,148
2 39 12	Szechwan Highlands	2	52,000
2 40 13	Macaronesian Islands	7	48,095
2 41 13	Ryukyu Islands	2	4,047
2 42 14	Lake Ladoga		0
2 43 14	Aral Sea	1	18,300
2 44 14	Lake Baikal		0
		1,027	52,878,456
3 01 01	Guinean Rain Forest	15	907,720
3 02 01	Congo Rain Forest	23	7,754,775
3 03 01	Malagasy Rain Forest	6	243,238
3 04 04	West African Woodland/Savanna	53	13,543,787
3 05 04	East African Woodland/Savanna	36	7,873,091
3 06 04	Congo Woodland/Savanna	5	2,990,700
3 07 04	Miombo Woodland/Savanna	33	13,396,995
3 08 04	South African Woodland/Savanna	105	10,437,555
3 09 04	Malagasy Woodland/Savanna	7	388,224
3 10 04	Malagasy Thorn Forest	1	43,200
3 11 06	Cape Sclerophyll	41	1,620,967
3 12 07	Western Sahel	7	1,726,000
3 13 07	Eastern Sahel	2	1,719,700
3 14 07	Somalian	18	4,142,182
3 15 07	Namib	7	6,768,070
3 16 07	Kalahari	8	9,282,803
3 17 07	Karroo	15	144,330
3 18 12	Ethiopian Highlands	5	636,000
3 19 12	Guinean Highlands	2	335,625
3 20 12	Central African Highlands	9	3,622,985
3 21 12	East African Highlands	9	431,108
3 22 12	South African Highlands	13	78,908

Table 4 (cont.): Analysis by biogeographical province

	Name of Province	Number of areas	Total area (hectares)
3 23 13	Ascension and St Helena Islands		0
3 24 13	Comores Islands and Aldabra	1	19,000
3 25 13	Mascarene Islands	3	4,033
3 26 14	Lake Rudolf		0
3 27 14	Lake Ukerewe (Victoria)	1	45,700
3 28 14	Lake Tanganyika		0
3 29 14	Lake Malawi (Nyasa)	1	9,400
		426	88,166,096
4 01 01	Malabar Rainforest	30	1,303,273
4 02 01	Ceylonese Rainforest	1	97,956
4 03 01	Bengalian Rainforest	22	657,352
4 04 01	Burman Rainforest		0
4 05 01	Indochinese Rainforest	28	1,780,756
4 06 01	South Chinese Rainforest	21	165,709
4 07 01	Malayan Rainforest	20	1,087,728
4 08 04	Indus-Ganges Monsoon Forest	136	6,835,608
4 09 04	Burma Monsoon Forest	18	515,429
4 10 04	Thailandian Monsoon Forest	20	942,417
4 11 04	Mahanadian	17	1,022,379
4 12 04	Coromandel	3	105,828
4 13 04	Ceylonese Monsoon Forest	36	544,709
4 14 04	Deccan Thorn Forest	8	454,036
4 15 07	Thar Desert	35	1,628,854
4 16 13	Seychelles and Amirantes Islands	2	2,893
4 17 13	Laccadives Islands		0
4 18 13	Maldives and Chagos Islands		0
4 19 13	Cocos-Keeling and Christmas Islands	1	1,600
4 20 13	Andaman and Nicobar Islands	8	28,592
4 21 13	Sumatra	29	4,253,807
4 22 13	Java	38	644,930
4 23 13	Lesser Sunda Islands	10	174,155
4 24 13	Sulawesi (Celebes)	22	1,093,265
4 25 13	Borneo	39	3,791,061
4 26 13	Philippines	26	390,932
4 27 13	Taiwan	2	45,137
		572	27,568,406
5 01 13	Papuan	24	3,747,672
5 02 13	Micronesian	5	13,258
5 03 13	Hawaiian	4	214,502
5 04 13	Southeastern Polynesian	8	53,977
5 05 13	Central Polynesian	4	44,055
5 06 13	New Caledonian	7	48,796

Table 4 (cont.): Analysis by biogeographical province

	Name of Province	Number of areas	Total area (hectares)
5 07 13	East Melanesian	2	5,342
		54	4,127 602
6 01 01	Queensland Coastal	53	7,776,347
6 02 02	Tasmanian	26	904,976
6 03 04	Northern Coastal	10	934,272
6 04 06	Western Sclerophyll	138	2,444,584
6 05 06	Southern Sclerophyll	56	1,413,727
6 06 06	Eastern Sclerophyll	95	2,741,356
6 07 06	Brigalow	12	319,156
6 08 07	Western Mulga	10	2,144,280
6 09 07	Central Desert	13	3,657,703
6 10 07	Southern Mulga/Saltbush	10	4,363,400
6 11 10	Northern Savanna	9	1,458,655
6 12 10	Northern Grasslands	3	582,738
6 13 11	Eastern Grasslands and Savannas	34	670,163
		469	29,411,357
7 01 02	Neozealandia	145	2,783,281
7 02 09	Maudlandia	6	34,959
7 03 09	Marielandia	1	160,000
7 04 09	Insulantarctica	5	100,075
		157	3,078,315
8 01 01	Campechean	4	63,918
8 02 01	Panamanian	6	660,902
8 03 01	Colombian Coastal	6	1,019,000
8 04 01	Guyanan	21	2,155,078
8 05 01	Amazonian	14	12,733,681
8 06 01	Madeiran	2	448,150
8 07 01	Serro Do Mar	8	196,468
8 08 02	Brazilian Rain Forest	16	447,233
8 09 02	Brazilian Planalto	2	15,839
8 10 02	Valdivian Forest	13	4,018,459
8 11 02	Chilean Nothofagus	7	4,367,307
8 12 04	Everglades	9	774,279
8 13 04	Sinaloan	5	462,994
8 14 04	Guerreran	5	66,873
8 15 04	Yucatecan	2	106,970
8 16 04	Central American	23	825,207
8 17 04	Venezuelan Dry Forest	26	1,125,794
8 18 04	Venezuelan Deciduous Forest	11	546,930

Table 4 (cont.): Analysis by biogeographical province

	Name of Province	Number of areas	Total area (hectares)
8 19 04	Equadorian Dry Forest	3	181,300
8 20 04	Caatinga	3	236,100
8 21 04	Gran Chaco	6	1,175,000
8 22 05	Chilean Araucaria Forest	1	5,415
8 23 06	Chilean Sclerophyll	5	38,795
8 24 07	Pacific Desert		0
8 25 07	Monte	7	1,446,751
8 26 08	Patagonian	4	36,700
8 27 10	Llanos	3	1,207,000
8 28 10	Campos Limpos	3	3,192,000
8 29 10	Babacu	1	155,000
8 30 10	Campos Cerrados	11	2,457,403
8 31 11	Argentinian Pampas		0
8 32 11	Uruguayan Pampas	9	70,516
8 33 12	Northern Andean	9	913,288
8 34 12	Colombian Montane	8	1,397,050
8 35 12	Yungas	9	1,108,268
8 36 12	Puna	13	1,168,439
8 37 12	Southern Andean	47	6,450,237
8 38 13	Bahamas-Bermudean	4	122,540
8 39 13	Cuban	4	24,305
8 40 13	Greater Antillean	9	225,230
8 41 13	Lesser Antillean	6	87,875
8 42 13	Revilla Gigedo Island		0
8 43 13	Cocos Island	1	3,200
8 44 13	Galapagos Islands	1	691,200
8 45 13	Fernando De Noronja Island	1	36,249
8 46 13	South Trinidade Island		0
8 47 14	Lake Titicaca		0
		348	52,464,943
	Biogeographical classification unknown	132	7,866,578
	TOTAL	3,514	423,774,398

An introduction to the
Protected Areas Data Unit,
IUCN Conservation Monitoring Centre

Jeremy Harrison
IUCN Conservation Monitoring Centre
219c Huntingdon Road
Cambridge CB3 0DL
United Kingdom

The work of the IUCN Conservation Monitoring Centre is
a contribution to the Global Environmental Monitoring System
of the United Nations Environment Programme

Cambridge, 1985

INTRODUCTION

For well over two decades IUCN has been collecting information on the world's conservation sites, both for use in its own programmes, and to assist in its work with other conservation organizations. During the late 1970s, IUCN's Commission on National Parks and Protected Areas (CNPPA) was reorganized on a regional basis and, as a part of this process, data-gathering on protected areas was made more systematic. The resulting increased flow of information created the need for an office to handle it, and the Protected Areas Data Unit (PADU) was set up in 1981 with the assistance of the United Nations Environment Programme (UNEP) and the US Nature Conservancy. The unit now forms part of the IUCN Conservation Monitoring Centre (CMC) and is based in Cambridge, in the United Kingdom. The information handling capabilities of the unit depend on a Wang VS mini-computer which provides an integrated data-processing and word-processing system. The following paragraphs give a brief outline to some of the work carried out by PADU, and provide an introduction to how the unit is integrated within IUCN's conservation monitoring activities. Further details on the development of the CMC computer database are discussed by Mackinder (1984).

HANDLING THE INFORMATION

IUCN has a worldwide network of contacts, many of whom can provide information on protected areas within their respective regions. Many of these contacts are members or consultants of IUCN's Commission on National Parks and Protected Areas (CNPPA), and PADU receives much of its information through the regional working sessions of the Commission which PADU staff attend, and where the participants are asked to review information on the region. Information collected in this way is added to through correspondence and literature research, and in discussion with scientists and land managers from around the world.

Information is received in a variety of forms ranging from departmental reports to scientific papers, though many contacts provide information on standard forms, or correct draft information sheets prepared by PADU staff. Although it is easier to deal with information sent on standard forms, it is important to also receive original information such as management plans, maps, departmental reports, scientific papers, and species lists. The availability of such documentation not only enables extraction of further information, and verification of information where necessary, it also means that if detailed information is required by IUCN for any given region the original documents can be quickly found and used.

Initially basic data are abstracted from the information received, and entered into the main data file on the computer. These files are constantly being extended, and the programs which handle them improved, but the core information includes the name of the protected area, the country it lies within, its size, year of establishment, management category (according to IUCN/CNPPA, 1984), its definition within the country (eg National Park, Nature Reserve), and its biogeographic code (according to Udvardy, 1975). Various other codes, such as document addresses (explained shortly), those indicating what sort of maps PADU has on file, and a unique number (one for each protected area) are used in cross-referencing information.

Using the computer this information can be handled in a wide variety of ways, and data items can be selected and sorted using any character or group of characters within the data file. It is possible, for example, to obtain a list of protected areas of over 100,000 hectares within the Tropical Humid Forest biome in Latin America, a list of sites in Burma and Thailand in IUCN management category I, or a list of all the protected areas established between 1954 and 1972. By sorting the data, it is relatively straightforward to put together volumes like the UN List (IUCN, 1982a; 1985b). In this case information is first selected from the data file, then sorted by country, by management category within country, by size within management category within country, and so on. The material which has been sorted can then be put into the right format by careful programming so that it is ready for publication.

Programs can also be written to summarise the information in a wide variety of ways, and several summaries have already been published by IUCN (1982a; 1985b), Harrison, Miller and McNeely (1982) and Unesco (1983). Two examples will perhaps illustrate this capability. By mid 1982, over 2,600 areas had been created which were considered to be of sufficient status to be included in the 1982 UN List, and the total area protected as of October 1982 included some 4 million square kilometres. The rate of growth to achieve this is illustrated in Figure 1 from information held and sorted by the computer. These data can be further broken down to illustrate the situation in each of the different realms (Figure 2), again using information selected from data files, and sorted appropriately. Using other programs, protected areas in IUCN management categories I-V can be sorted into size classes facilitating the plotting of frequency histograms (Figure 3).

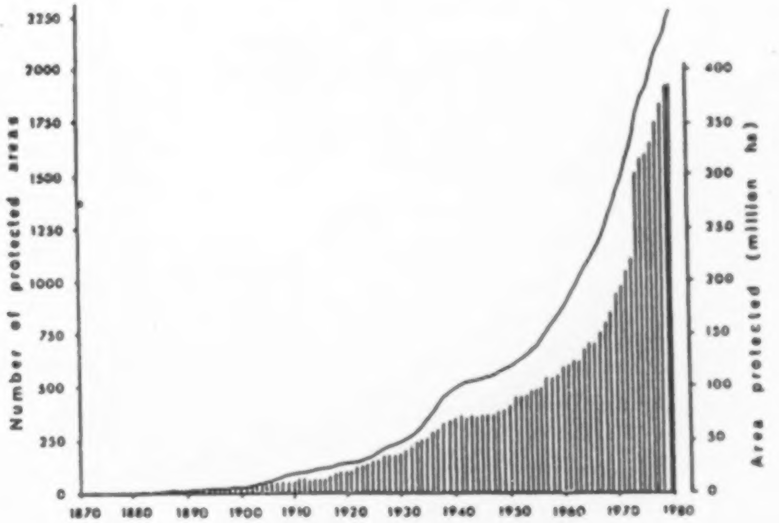


Figure 1 Growth of the world coverage of protected areas (——) number, (||||||) total area in hectares.

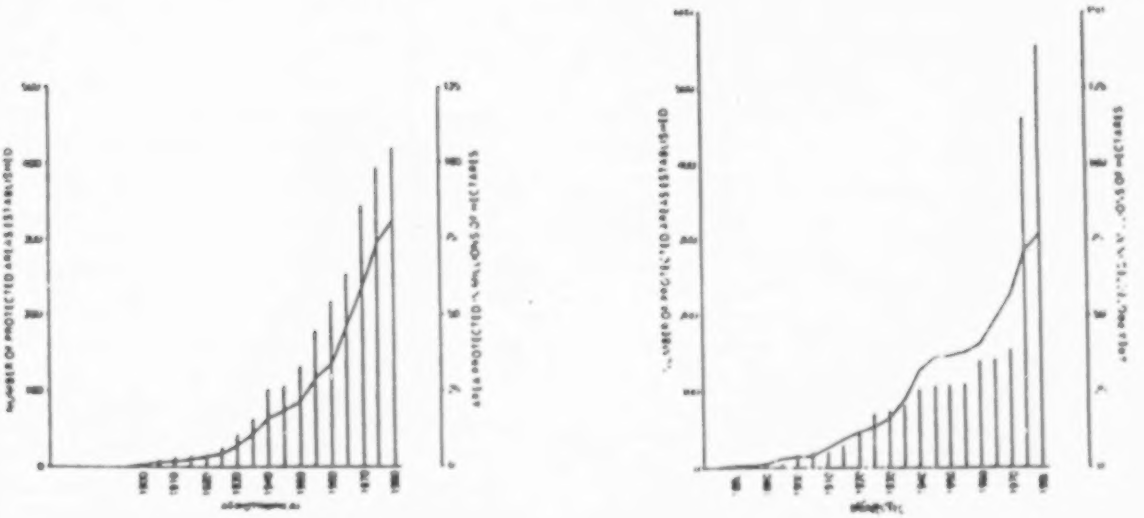


Figure 2 Growth of regional protected areas coverage (——) number, (||||||) total area in hectares.

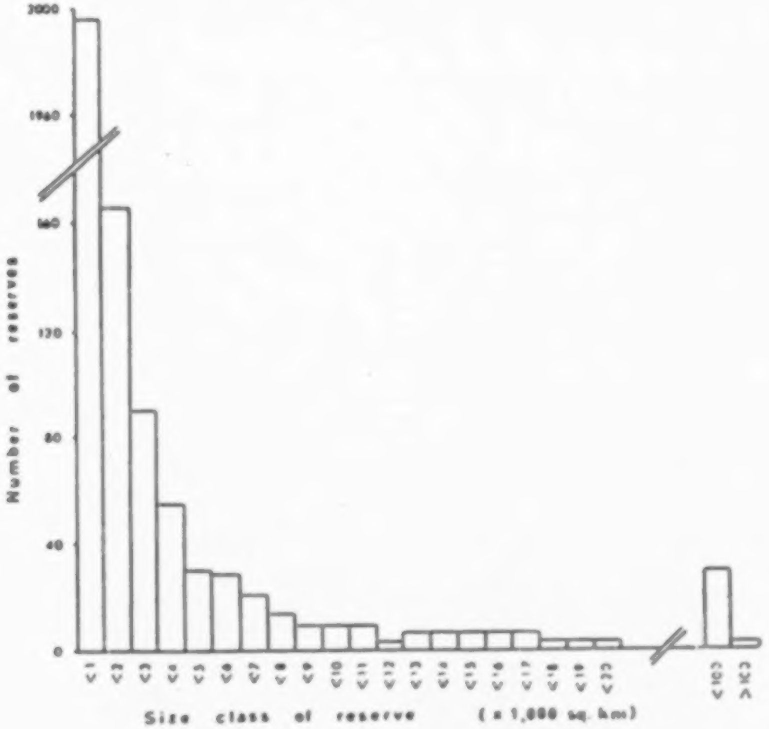


Figure 3 Size distribution of protected areas in IUCN management categories I-V

Use of the data files is only half the story. Data on each area are compiled into an 'information sheet' where information is grouped under a number of specific headings (Figure 4). As noted earlier, the information may already have been supplied to in this format. Each of these information sheets is entered into the computer as a word processing document or text file. The text can be stored by the machine and recalled for correction or reformating whenever necessary. Each text file has a document identification, and it is this number which we enter into our data file as the document address mentioned above. This gives is the essential cross-link between the basic information and the detailed text.

The information in these text files is regularly checked and added to, using material from various sources. More systematic checking is accomplished by taking all of the sheets for any given region to each CNPPA meeting in that region for review. In this way, material can be prepared for publication. The IUCN Directory of Neotropical Protected Areas was published at the time of the World National Parks Congress in Bali, Indonesia (IUCN, 1982b), and during 1984 final drafts of both the Directory of Wetlands of International Importance (IUCN, 1984) and the IUCN Directory of Afrotropical Protected Areas were prepared. The Afrotropical Directory will be published shortly (IUCN, 1985a), and work is now in progress on both the Indomalayan and Oceanian regions.

Name of protected area
Management category
Biogeographic province
Legal protection
Date established
Geographical location
Altitude
Size of area
Land tenure
Physical features
Habitat/Vegetation
Noteworthy flora
Noteworthy fauna
Conservation management
Zoning
Disturbances and deficiencies
Visitor facilities
Scientific research/facilities
Principal reference material
Staff
Budget
Local administration

Figure 4 The major headings under which information is collected on protected area information sheets

The word-processing system is also being used to manage the documentation on World Heritage sites for the secretariat at Unesco, and plans are under way to carry out similar projects for biosphere reserves and sites listed under the Convention on Wetlands of International Importance Especially as Waterfowl Habitat.

USE OF THE INFORMATION

It is abundantly clear that any one country will have far more information available on its own protected areas than could ever be handled by a few people in an office in the United Kingdom. Similarly many countries have the capacity to establish computer systems and are able to maintain their own information on protected areas in ways that meet their own needs. How then does PADU aid conservation? There are in fact a variety of reasons, of varying levels of importance, for maintaining a global overview.

a) Broad comparisons of protected areas networks

Around the world there are many different designations of protected area. In Kenya, for example, the terms include national parks, national reserves, nature reserves, forest reserves, and in Spain national parks, natural parks and national hunting reserves. In Thailand there are areas known as no hunting areas, in Uganda game management areas, while in Kiribati similar areas are designated wildlife sanctuaries. However, the definitions of any one designation will vary country to country, for example the national parks of the United Kingdom are certainly not national parks in any international sense.

In an attempt to clarify this situation, and to encourage the use of a wide range of protected area 'types', IUCN (1978) identified a series of ten management categories defined according to management objectives. PADU is using these ten categories to classify areas, and hence is able to give a better comparative picture of the protected area situation country to country than could be achieved by use of the national designations.

b) Biogeographical analysis of protected area coverage

A major objective of the global protected area system is to maintain the diversity of species and ecosystems, but listing protected area coverage by country does not provide much information on how well natural ecosystems around the world are being conserved. IUCN has therefore been using the system of biogeographical provinces described by Udvardy (1975) to make a first estimate of the coverage of major living resources by protected areas. This system divides the world into eight major realms, each of which is divided into a number of provinces. Each province is characterised by a particular biome type. Hence the Akagera National Park in Rwanda, for example, is within the **Afrotropical Realm**, in the **East African Woodland/Savanna Province**, which is characterised by a **tropical dry or deciduous forests or woodlands** biome.

A first approach to assessment of coverage of the world's biogeographic variety by protected areas is to examine coverage by province and biome. At present such comparisons are relatively crude, and it is important to note, for example, that biome type is not synonymous with habitat type, and also that the total area of each province or biome is not the same; problems which can hide important differences in the figures (Harrison et al, 1982). However, for all of its limitations the approach through biogeographic provinces does provide a useful tool for identifying major holes in the protected area network. For example 13 of the biogeographical provinces did not have protected areas included in the 1982 UN List, and some 34 provinces had 5 or fewer protected areas covering an area of less than 100,000 hectares. The rather crude tool of global biogeography could therefore suggest that these poorly protected provinces may be where international attention should be focussed. We know that coverage is patchy. To determine exactly how patchy, more analysis of the figures is required, based on more accurate estimations of the size of the biomes and provinces; this work is in progress.

It is clear that the global biogeographical approach provides useful information primarily at the global level: For national systems, the same biogeographic principles can be applied with considerably greater precision yielding proportionally more useful results; examples of such applications include those in Costa Rica, Canada, New Zealand, and in the Amazonian region of Brazil. Also, with more detailed continent-wide biogeographic maps, such as the vegetation map of Africa (Unesco/AETFAT/UNSO, 1983), it is possible to make more accurate assessments of protected area cover at this level. The information held by PADU is currently being used in the development of protected areas systems plans for two of the major tropical regions, the Afrotropical and Indomalayan realms. This project is described in detail by MacKinnon (1985).

The system of marine biophysical provinces and coastal biogeographical provinces described at the World National Parks Congress in Bali, Indonesia (Hayden et al, 1984), has important applications in identifying the major gaps and weaknesses in the present coverage of coastal and marine ecosystems. This is something that has not been systematically tackled before for the whole world, and should lead to a significant increase in the number and size of protected areas in these aquatic habitats. Work will begin on this shortly.

c) Development of publications on protected areas

Having all this information available on one site enables PADU to work with CNPPA in developing a variety of publications on protected areas. The United Nations List has already been mentioned, as has the series of directories of protected areas. The directories, which give basic details on the protected area networks of each country and one or two pages of information on each protected area, are intended to serve as handbooks for the protected areas of each major land mass. Volumes on the Neotropical Realm and the Afrotropical Realm have been produced so far (IUCN, 1982b; 1985a), and work is now under way on volumes to cover the Indomalayan and Oceanian realms.

PADU is also in a good position to prepare or help prepare general overview papers on protected areas issues.

It is also possible to produce publications on request; a volume on a particular country; on the vegetation of parks and reserves of South East Asia; on the protected areas of tropical rain forest around the world; on the threats to all protected areas containing tigers, bowerbirds, or coco de mer; or on those areas set up to protect important watersheds, or protected under specific international conventions or programmes. Some of these would be more difficult to produce than others, but we already hold much of the necessary information.

d) Providing information to conservation agencies

IUCN, the World Wildlife Fund, and other international conservation agencies need a basis for determining high priority areas for allocation of scarce conservation funds. Using PADU, IUCN is in a position to supply essential background information on protected areas. For example, the results of the projects mentioned above to evaluate protected area coverage in the tropics will have direct effects on the conservation efforts made by IUCN and others in different parts of each region.

The World Heritage Convention requires global information in order to ensure that sites inscribed on the World Heritage List are of truly "outstanding universal significance". IUCN is responsible for the technical evaluation of natural sites nominated for inclusion on this list, and the information held on these sites by PADU is an important component of this work. In the future, analyses of the information available on natural World Heritage Sites will be required in order to assess the working of the Convention, and to systematise the information on what is listed under it. Because of its developing expertise in this field, PADU is perhaps in the best position to do this type of work - in particular because of the possibilities for comparison of World Heritage Sites with other protected areas.

Unesco's Man and the Biosphere Programme requires global information to ensure that representative areas of all biogeographic provinces are established as Biosphere Reserves. Much of the information available on Biosphere Reserves also needs to be analysed. PADU is already in a position to carry out some of this work, and produced analyses of Biosphere Reserve information for the First International Congress on Biosphere Reserves in Minsk, Byelorussia (Unesco, 1983). As with World Heritage Sites there is a need for a more systematic monitoring system, and it is hoped that in the future PADU will be able to provide this type of service.

PADU also acts as the repository for information on sites listed under the Convention on Wetlands of International Importance Especially as Waterfowl Habitat (Ramsar, 1971), and is responsible for maintaining an up-to-date list of sites. As with all other areas discussed, an information sheet for each site is also prepared, and a draft directory of these sites was presented to the second conference of contracting parties to the convention in Groningen (IUCN, 1984).

e) Providing information to aid agencies

If international development agencies such as the World Bank and US-AID could be provided with quick, accurate, large-scale overviews of protected areas needs and problems, they would be in a position to avoid adversely affecting particularly sensitive areas. Also, if they could be given the right background on all the conservation issues in the area concerned, they would perhaps be able to design their projects to enhance sustainable development.

PADU would not be in a position to supply all of the information itself, but by incorporating data held by PADU with that held by other units of CMC, IUCN could give the agency concerned a good introduction to conservation needs and problems in the region, and perhaps help further by suggesting consultants to carry out the vital field assessments. Reports of this kind prepared so far by CMC include preliminary environmental profiles of the Sind-Kutch region of the India-Pakistan borderlands, and of the Madhya Pradesh region of central India.

This type of information might also be of interest to a wide range of multinational companies.

f) Providing information to governments

Many governments need to know what is being done in the field of protected areas management elsewhere, in order to enhance their own efforts and to avoid repeating mistakes. In particular, information is required by two groups of people, the decision makers and the management agencies, who require background information on which to base and justify decisions. The biogeographical analyses mentioned above will be of relevance here, for example, as they can be used as strong arguments for the siting of protected areas in given regions. Management agencies may be more in need of technical assistance, for example on some particular management problem. A centralised source of information will hopefully be able to detail where this type of work has been done before.

In large countries (such as the United States of America) there are many different types of protected area, run by a variety of agencies. In some cases, our efforts to collect this type of information may mean that such national information is being collected together in one site for the first time.

Manipulating conservation data by computer is still a relatively new field and it may be some time before governments develop their own information systems. IUCN is developing a strong capability in the use of computers for conservation, and this expertise could be made available to those needing assistance in setting up their own systems.

g) Providing information to scientists

Scientists often need to make comparisons over a wide range of habitat types, or over complete species ranges. Information on the species and habitats in protected areas may therefore be of particular use in pinpointing research sites or illustrating distributions. Analyses of site protection are also being carried out, and information held by PADU has helped in projects as diverse as the identification of coastal wetland protected areas in the Neotropics, and an assessment of the workability of the Gunung Mulu management plan.

There are also numerous examples of the application of a protected area database in the area of genetic resource conservation. A plant breeder, for example, may need to know where wild ancestors of particular domestic agricultural crops can be found in protected areas, in order to locate sources of genetic diversity for improving crop breeds. This type of information is not available at present, but we are working towards it, and various proposals made to IUCN and others, if carried out, will increase the available information considerably.

Information is also required by scientists planning expeditions. Provision of such advance information can be important in project development, and may lead to a greater emphasis on conservation and management needs.

h) Providing information for education and training

It is of particular value both in the teaching of nature conservation and in the training of nature conservation personnel to put what is being taught into a global or regional context. Analyses and syntheses of the information held by PADU can be used by teachers and trainers to provide that context. PADU can also make available original material such as maps and management plans which can be used in developing education and training programmes.

i) Providing information to the media

The international effort to promote protected areas requires a centralized source of information for publications, requests from journalists, and other promotional and publicity uses. If this type of information is available from a central office, journalists, writers and broadcasters can quickly obtain information on both the issue concerned and the background to it. For instance during the recent South-West Tasmania argument, PADU was able to give not only information on the national parks of that area, but also on the World Heritage Convention (and to further draw attention to the fact that the UK had not at the time ratified the convention). In addition lists were provided of a number of other sites that had been (or were) threatened by damming projects, together with some background information on these areas. In other words a central information office on protected areas is of value in ensuring adequate and accurate media coverage of issues concerning protected areas.

Any of PADU's outputs could be produced by other individuals or organizations given sufficient time and energy, and sufficient back-up - PADU only provides what is fed into it. But the amount of information already available to PADU, and the fact that much of it is already on computer, means that we have the capability of reproducing the data quickly, providing analyses as necessary, and providing the outputs in a wide variety of configurations. We will not replace any of the human element in protected area management, but should allow managers, development planners, conservationists, and scientists to be more efficient by providing the data they require, when it is needed, and in the form required.

Perhaps more importantly, collection and presentation of protected areas information in a professional and competent manner demonstrates to governments, development agencies, and individuals around the world that national parks and reserves are valuable land-use tools for managing areas which should, for various reasons, be kept in a natural or semi-natural state. Making data on protected areas more accessible will help to ensure that the reserves can play their proper role in resource management and development.

FUTURE DIRECTIONS

PADU is still developing, and is not yet in a position to do all we would like. For example, currently information cannot be sorted by habitat or vegetation type. As noted earlier, this means that it is not possible to produce lists of protected areas protecting tropical rain forests, although we can produce lists of areas within a tropical humid forest biome. Therefore a future need is the development and implementation of a coding system which would allow us to do this. Implementation will involve sorting through our files manually and assigning habitat codes for each protected area, codes which can then put into the computer files. This process will take some time.

Information is gradually being extracted from our manual files and from the text files on the computer so that the data sorting and selection facilities can become even more useful. In the future, for example, we hope to be able to sort information on criteria such as the practical benefits accruing from a protected area (watershed management, inshore fisheries protection, etc), on climatological or geomorphological characteristics, and of course on the indigenous flora and fauna. Work is already underway on pilot projects to link the protected area data files with those on threatened animals and plants managed by other parts of the Conservation Monitoring Centre. CMC is rapidly working towards greater integration at all levels (see Mackinder, 1984), and we use a number of common programs and files on the computer (particularly those concerned with geographical location, and with bibliographies). Future developments will include the integration of computer mapping and map handling techniques.

National conservation databases are now being developed or planned in several countries, and CMC is already working with a number of these. Working with such databases has the dual advantage that not only is much of our information coming from one source, but also that it can be sent to us in computer compatible form. Information on parks and reserves in both New Zealand and South Africa, for example, has been supplied on computer diskette, and most of the information on the subantarctic islands has also been supplied in this way. CMC's senior programmer has been assisting various conservation organizations in managing information on micro-computers, and again we are able to accept information directly from many of these machines.

Despite all these developments and the evident usefulness of PADU and CMC, the ability to carry out all of the tasks required ultimately depends on the information available, and our capacity to make use of that information. For outputs to be of most use to conservation planners at all levels, the data need to be both flexible and broadly based. This is a central aim of our operation. Crucial to this aim is the maintenance of high quality, accurate, information, and this is leading to the development of an ever broadening contact network. Currently our information is patchy, and we know that much more work must be done in improving it. This work is under way.

THE WIDER IMPLICATIONS

As the number and extent of protected areas continues to increase, and as the existing networks develop, management will in the future need to be much more effective, and integrated on an international scale. Managers must define clear objectives for each site, and make hard decisions to attain these objectives (especially where there are many alternative demands on an area). Effective management depends ultimately on knowledge, and the disseminaton of that knowledge, be it on management techniques, or on ecosystems and their management needs.

This knowledge can be, and is being, gleaned at the local level by scientists and conservationists throughout the world, but can be put to best use if it is gathered and disseminated not just at a local level, but also through a central office (facilitating, for example, the application of global arguments to local issues). If this is done through the framework of international organizations, then the results can in many instances be even more powerful and useful than if those same functions were performed independently at national or regional level. IUCN is aiming to provide such an international framework through its Conservation Monitoring Centre.

However, for conservation ideals to become more fully integrated into management and management planning on a global scale, information is required from a far wider range of disciplines than those normally associated with 'nature conservation'. The Global Environment Monitoring System (GEMS) was set up by the United Nations Environment Programme to "keep track of environmental trends, to be able to predict events and to provide decision-makers with sound information upon which to base environment action plans" (UNEP, 1982). They are now in the process of establishing a Global Resource Information Database (GRID), of which CMC will be a part. GEMS is not an organization, but a programme, coordinating and directing existing talent and facilities, making use of organizations such as the World Health and Meteorological Organizations, the Food and Agriculture Organization, Unesco, and of course IUCN (Croze, 1984).

If GEMS is the hub of the wheel of organizations associated with the environment, CMC occupies a similar position with respect to organizations and government departments associated with nature conservation, and within CMC, PADU deals with that sector of CMC work relating to protected areas and protected area issues. The organization is involved, and acronyms abound, but this should not detract from the value, and indeed the necessity of the work. For many reasons our environment requires management; the key to successful management of the environment is information.

REFERENCES

Croze, Harvey (1984). Global monitoring and biosphere reserves. In Unesco-UNEP, Conservation, science and society. Unesco, Paris.

Hayden, B.P., Ray, Carleton & Dolan, R. (1984). Classification of Coastal and Marine Environments. Environmental Conservation 11(3): 199-207.

Harrison, J., Miller, K. & McNeely, J. (1982). The world coverage of protected areas: Development goals and environment needs. Ambio XI(2), 238-245.

IUCN (1982a). 1982 United Nations List of National Parks and Protected Areas. IUCN, Gland.

IUCN (1982b). IUCN Directory of Neotropical Protected Areas. IUCN, Gland.

IUCN (1984). Draft Directory of Wetlands of International Importance. IUCN, Cambridge.

IUCN (1985a). IUCN Directory of Afrotropical Protected Areas. IUCN, Gland and Cambridge.

IUCN (1985b). 1985 United Nations List of National Parks and Protected Areas. IUCN, Gland and Cambridge.

IUCN/CNPPA (1984). Categories, objectives and criteria for protected areas. In McNeely, Jeffrey A. and Miller, Kenton R. (Eds.) National Parks, Conservation and Development: The Role of Protected Areas in Sustaining Society. Smithsonian Institution Press, Washington.

Mackinder, D.C. (1984). The database of the IUCN Conservation Monitoring Centre. In Allkin, R. and Bisby, F.A. (Eds.) Databases in Systematics. Academic Press, London.

MacKinnon, John (1985). Outline of methodology for preparation of a review of the protected areas system of the Afro-tropical realm. Proceedings of the twenty-fifth working session of IUCN's Commission on National Parks and Protected Areas, Corbett National Park, India, 4-8 February, 1985. IUCN, Gland.

Udvardy, M.D.F. (1975). A classification of the biogeographical provinces of the world. IUCN Occasional Paper No. 18. IUCN, Morges.

UNEP (1982). GEMS. UNEP, Nairobi.

Unesco (1983). MAB Information System: Biosphere Reserves. Compilation 3. Unesco, Paris. (Prepared for Unesco by the IUCN Conservation Monitoring Centre.)

Unesco/AETFAT/UNSO (1983). Vegation Map of Africa. Unesco, Paris.

The first version of this paper was prepared from a presentation made to the World National Parks Congress, October 1982, and presented to the Bureau of the World Heritage Committee in 1983. A revised version was prepared for the 16th IWCN General Assembly in Madrid, October 1984. The paper has again been revised May 1985 for presentation to a CNPPA Working Group on Data Collection and Monitoring.

MONITORING ENVIRONMENTAL CONSERVATION: TOWARDS AN INTEGRATED GLOBAL OVERVIEW

IUCN Conservation Monitoring Centre
219c Huntingdon Road
Cambridge, United Kingdom

The International Union for Conservation of Nature and Natural Resources (IUCN) is essentially a global network of governments, governmental agencies, non-governmental organisations, scientists and other conservationists joined together in the common cause of promoting the protection and sustainable use of living natural resources. In undertaking this mission, one of IUCN's principal functions has been the gathering of data on species and habitats under threat, in order that scientifically-based conservation actions might be taken.

With 537 members located in 116 countries and having the ability to tap the knowledge of the some 2,000 technical experts comprising IUCN's six Commissions and their working groups, this network is capable of gathering a vast amount of information which is directly relevant to environmental conservation. A historical difficulty of the network, however, has been the lack of an effective ability to archive the data, update them and rapidly retrieve them when required. The need for this central focus gave rise to IUCN's Conservation Monitoring Centre (CMC) which now has the mission of handling and putting to best advantage the amount of data being received.

In undertaking this task CMC has utilised computer technology to develop a global database on species, wildlife trade, protected areas, habitats and ecosystems of conservation concern. Such computerisation has led to the ability to integrate and overlay the data in a variety of new and unique ways. CMC is thus not constrained merely to considering questions about a single species or area, but is capable of analysing quite complex issues. For example, an application recently undertaken consists of identifying the 100-200 sites globally whose protection would do most for plant conservation.

In addition to reviewing the structure, function and operations of CMC, this paper thus cites examples of how the database has contributed to the resolution of global conservation concerns. Also discussed is how the monitoring network might be improved in order to enhance CMC's abilities to provide a global perspective.

WHAT DOES THE CONSERVATION MONITORING CENTRE DO?

The primary function of CMC is the continuous collection, analysis, interpretation and dissemination of data as a basis for conservation. Species, habitats and areas of relevant conservation concern include those having current or potential economic import as well as those believed to be under threat.

CMC undertakes its function by integrating four monitoring activities (our major management units) which cover the status of:

- * Animal species (Species Conservation Monitoring Unit)
- * Plant species (Threatened Plants Unit)
- * Wildlife trade (Wildlife Trade Monitoring Unit)
- * Protected areas (Protected Areas Data Unit)

Data resulting from these activities are linked by common geographical and taxonomic coding systems within the computer. The result is a highly sophisticated database capable of producing integrated outputs on a wide range of contemporary conservation issues.

CMC disseminates this information through a series of publications, including the renowned IUCN Red Data Books on plants and animals, and by producing special reports tailored to the needs of clients.

WHERE DOES THE INFORMATION COME FROM?

The accuracy and relevance of CMC's data are owed to an unrivalled network of organizations and specialists all over the world. These include:

** The network of IUCN members, which include governments, government agencies and non-governmental organizations that make IUCN the international union of conservation organizations.

** The international network of scientists and other cooperators affiliated to IUCN and its six commissions. Our principal contacts, the combined memberships of the Species Survival Commission, the Commission on National Parks and Protected Areas and the Commission on Ecology, number over 2,000 individuals worldwide.

** The researchers under contract for over 300 IUCN/WWF field projects annually.

** The IUCN Environmental Law Centre, which provides a similar service to ours but on legal matters, and the IUCN Conservation for Development Centre, which maintains a roster of consultants able to undertake conservation and development projects.

** The network of TRAFFIC offices (Trade Records Analysis of Flora and Fauna In Commerce). Established in several countries, each office monitors trade in wildlife to and from its region. CMC co-ordinates them and draws on their data.

** The professional contacts set up by CMC staff with colleagues around the world. CMC staff call upon the knowledge and experience of scientists and conservation experts who work in government agencies, universities, zoos and botanic gardens, and museums and libraries.

** International organizations with whom we cooperate. In particular CMC works with the International Council for Bird Preservation (ICBP), the International Wildfowl Research Bureau (IWRB), the UN Food and Agriculture Organization (FAO), the UN Environment

Programme (UNEP), and the UN Educational, Scientific and Cultural Organisation (Unesco).

Although CMC staff are not usually sent into the field themselves they are thus in direct contact with those individuals who are at the forefront of conservation action. On any one subject CMC staff can seek the guidance of the foremost experts in the world.

WHAT DO WE DO WITH THE INFORMATION?

Once the raw data have been collected and verified, they are critically interpreted, summarised and entered into the computer in two different yet complementary forms:

** Text is handled in a word-processing system and can be as detailed and extensive as required. It can be rapidly modified to incorporate new information.

** Data files. Summaries of the information are coded into data files, permitting rapid processing and analysis. This is done because computers cannot efficiently extract and sort information from plain text.

The two types of file are linked by common geographical and taxonomic coding systems. This dual approach produces an unusually flexible system, giving CMC the advantage of rapid computer selection and sorting of information but avoiding the problem of forcing variable biological data into a rigid data processing format. The information on computer is backed up by more detailed material on manual files and the capability to locate and contact the relevant experts on any particular issue. CMC is thus well equipped to respond rapidly and accurately to requests for information.

HOW IS CMC ORGANISED?

a) Monitoring the status of animals

Animals, particularly vertebrates, have been the traditional focus of many IUCN/WWF conservation projects. This emphasis has generated a demand from many sectors for quite specific data on the conservation status of a wide range of animal species. Monitoring activities have consequently developed to answer this demand and led to the publication of the internationally respected IUCN Red Data Books, a series of authoritative references on threatened species. Collection of data for this series continues to provide an important focus for CMC's work.

However, the collection of data is not confined just to threatened species. The database includes information on all species of conservation concern, including widespread but depleted wild taxa of economic importance, and wild relatives of domestic stock.

Although continually under development, the animal data-file currently contains summary information on 17,000 taxa of conservation concern. Detailed 'Red Data Book' accounts have been prepared for 2,000 of these taxa. These sheets provide comprehensive information on distribution, population status, habitat needs, ecology, threats to survival and proposed conservation measures, along with a comprehensive reference list.

Information on individual species is readily available for the higher vertebrates (birds and mammals) but different approaches have had to be developed for the less well studied lower vertebrates (fish, reptiles and amphibians) and invertebrates. These approaches have included the collection of data on an area basis, e.g. on such specific places as the Banks Peninsular in New Zealand or the Usambara Mountains in Tanzania, or on specific habitats such as coral reefs. This work links up with other area-based information in the CMC database, particularly that on plant sites and protected areas.

b) Monitoring the status of plants

The increasing demand for information on the conservation status of plants has accompanied the growing realisation that plant species are critical for maintaining the ecosystems upon which mankind relies. In 1970 only Belgium had produced a list of its threatened plants. Today, virtually all countries of the geopolitical 'North' (including Australia, New Zealand and South Africa) have produced threatened plants lists, often as national Red Data Books. Many countries of the 'South' are now taking similar action. This rapid progress has coincided with a decade of intense activity by IUCN on threatened plants, much of it dedicated to encouraging and helping countries to document their threatened plants.

With estimates of the world's threatened flora ranging up to 40,000 species, no one book could attempt to list them all, let alone describe them in detail. However, with computer assistance, CMC is able to monitor a major proportion of the key species identified by our information networks. Although still under development, the CMC database now holds basic information on 30,000 plant taxa and provides a basis on which to plan the conservation of plants around the world.

Knowing which species are threatened in the wild also enables CMC to monitor their status ex situ (off-site), principally in botanic gardens. The plant data-file is used to produce lists of threatened species which are circulated to the 130 gardens that subscribe to IUCN's Botanic Gardens Conservation Co-ordinating Body. Gardens then return lists of the threatened species that they grow. The aim is to help gardens work as a network, avoiding duplication and contributing to the cause of preserving plant genetic resources.

Whereas the plant data-file contains many species found in temperate and subtropical climates or on islands, most of the world's plants occur in the less studied mainland tropics where habitat destruction is accelerating. Because of the size of the flora involved in these areas, a species approach is less practical, and alternatives are being investigated. These include gathering data on specific groups of plants such as those of economic or medicinal value, or those threatened by trade or habitat destruction. These floristic data are being used to identify key sites for conservation, leading to the publication of a Plant Sites Directory that identifies which areas of the world are most significant for plant conservation.

c) Monitoring wildlife trade

Trade in wild species and their products has become an immense, multi-million dollar enterprise, encompassing many diverse products ranging from rhino horn to coral and from exotic butterflies to tropical hard woods. Trade in threatened species of animals and plants has particularly aroused public concern. Through its Wildlife Trade Monitoring Unit, CMC collects information on the volume and trends of all such trade, and especially on the implementation and effectiveness of the international measures designed to control it.

One of the major initiatives in this area is the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES). Parties to CITES are required to submit annual reports to the CITES Secretariat, detailing permits issued for international trade in taxa protected by the Convention. Data from these reports are managed by CMC under contract to the CITES Secretariat. Currently 210,000 records of wildlife trade transactions are logged on the computer, representing reports submitted to CITES over the last nine years.

The analysis of these data provides an indication of the impact of trade on the species listed on the CITES appendices. It also allows comparisons to be made between trade statistics for importing and exporting countries. The discrepancies revealed give an insight into how well the Convention is being implemented. The presentation of such analyses enables the Parties to pinpoint ways in which the Convention is not working and to identify measures for making it more effective.

The CITES data are complemented by information collected from consultants and correspondents around the world, from the 'TRAFFIC' network of national trade monitoring offices, from reports on wildlife trade and from the published import and export statistics for a number of countries. Coupling this extensive data-file with those for animals and plants has enabled CMC to undertake a wide variety of special trade analyses under contract to international and governmental agencies, non-governmental organizations, and trade associations. Such projects recently included analyses of wildlife farming and ranching, international trade in elephant ivory, international trade in marine mammals, and the extent of trade in kangaroos, seals and corals. The TRAFFIC Bulletin, published five times per year, carries reports on these special analyses, as well as recent trade news.

d) Monitoring protected areas

A principal method used for the conservation of species and ecosystems is the protection of sites. To be able to plan effectively, both conservation and development agencies need to know which sites are already protected, how successfully they are managed, and what they contain in terms of animals, plants and critical habitats. CMC maintains a comprehensive overview of protected areas around the world, with summary data in the computer on over 10,000 sites and detailed accounts on 3,000 of these areas so far.

At the request of the United Nations, a summary of the protected areas data-file is published periodically as the UN List of National Parks and Protected Areas. CMC also publishes, with IUCN's Commission on National Parks and Protected Areas, detailed accounts of sites occurring in various realms of the world in the series of IUCN Directories on Protected Areas.

Apart from the ability to provide information on protected areas to interested parties, the linking of this information with other files in the database enables CMC to help CNPPA identify significant gaps in protected area coverage worldwide and subsequently to help plan conservation action. In particular, new approaches are being undertaken to survey protected area coverage in various parts of the tropics using CMC data to provide the initial overview on which further study can be based.

CMC has also developed databases on sites of concern under contract to other organizations. Such efforts have recently included maintaining a database for Unesco on natural sites listed under the World Heritage Convention, assisting them further by managing information on Biosphere Reserves, and establishing a prototype database on sites listed under the Ramsar Wetlands Convention.

e) Monitoring the status of significant ecosystems

Certain ecosystem types are of particular conservation interest and it therefore becomes important to try to inventory and describe the major sites where these ecosystem types occur. CMC has been involved for several years in the development of an information base on coral reefs, for example. More recently CMC has also become involved in the development of a wetlands database, based on the results of various projects to inventory and describe internationally important wetlands in various parts of the world.

These aspects of the database are of particular importance in assessing the conservation status of the respective habitat types covered. They also facilitate the development of proposals to protect, or to better conserve such areas.

HOW DOES IT ALL FIT TOGETHER?

CMC is capable of producing integrated outputs which draw upon all files within the database. This is possible because the information is linked by a common skeleton of taxonomic and geographic names. The system also records the relationship of these taxonomic or geographical names to others within a variety of hierarchical systems (e.g., species within families, counties within states). Sorting of data files to obtain the information needed by clients can thus be accomplished relatively quickly, and the linkage of data files with the text files enables reports to be developed rapidly.

CMC is also developing new database components, drawing information from the four existing major data files. In particular, as has been mentioned, area-based information is being synthesized for specific habitats which will be the subject of new international conservation initiatives: coral reefs, wetlands, oceanic islands, etc.

WHAT HAS CMC ACHIEVED?

CMC is a young organization and has spent much time developing the conservation database. Nevertheless the following achievements illustrate that the Centre has already progressed well towards the goal of being able to provide timely advice on conservation and development issues. We have:

** Defined new areas of conservation concern. CMC published the IUCN Invertebrate Red Data Book in 1983 as the first attempt to bring the international problem of threatened invertebrates to public attention. It has sold well and has been reviewed internationally from Chile to Hong Kong. Many important initiatives including field projects, surveys, captive breeding programmes, meetings and legislation followed its publication.

** Developed a lead in plant conservation. During 1983-84 CMC helped prepare the IUCN/WWF programme and campaign to promote plant conservation around the world. The database showed which places in the world had the greatest diversity of plant life and where among these places the threats were most acute, a vital ingredient for choosing the limited number of countries in which IUCN/WWF could reasonably sponsor projects. The programme is now running and with its combination of strategic and field projects, it not only sets new ground for IUCN/WWF, but is beginning to make plant conservation a more accepted part of conservation as a whole.

** Provided background information and a rationale for new legislation. Based on CMC data, IUCN submitted a formal memorandum to the Council of Europe describing how their Bern Convention could work for plants. IUCN suggested criteria to select plants for inclusion under the Convention and applied these to the database to produce a list of 119 species. These were accepted without dispute. This illustrates how CMC can act as a bridge between scientists and politicians. Only scientists know which plants are threatened, but politicians can only work to avert the threats if appropriately informed.

** Helped conservation organizations lobby governments better. In early 1983 a wealthy American asked the British Government for permission to settle on Henderson Island, an uninhabited coral island in the middle of the Pacific. At the request of WWF, CMC assisted in the preparation of a report for submission to the British Government regarding the island's unique flora and fauna. These and other efforts were rewarded when the Government announced that Henderson Island would not be settled.

** Provided crucial statistics on success of conservation measures. In 1983, CMC informed the Parties to CITES at their regular biennial meeting that as much as 45% of transactions in animal trade and 79% in plant trade in species of concern to CITES were not being reported as required. The analysis indicated that the Parties had far to go in making CITES an effective conservation body. CMC's ability to supply such precise figures provides powerful incentive for concerned governments and bodies to improve their compliance with agreed measures.

** Assisted forward planning for development projects. During 1984-1985 CMC assisted the development community through the provision of conservation briefings. These are resumes of available information on threatened species, critical habitats, parks and reserves, along with pertinent bibliographic citations and contact names, which indicate the key conservation issues that a potential development might encounter. Clients, including the World Bank and firms in the oil industry, have indicated that such briefings tailored to their specific needs have been extremely useful in pre-project planning and evaluation.

FUTURE DIRECTIONS

CMC is still developing and not yet in a position to do everything that is planned. To take one example, information on protected areas or species cannot currently be easily sorted by habitat or vegetation type using the computer, and if this needs to be done it must be done by hand. A future need is the therefore development and implementation of a coding system which would allow us to do this.

Information is gradually being extracted from our manual files and from the text files on the computer so that the data sorting and selection facilities can become even more useful. In the future, for example, we hope to be able to sort information on criteria such as the practical benefits accruing from a protected area (watershed management, inshore fisheries protection, etc) or specific habitat type such as a wetland. Projects are also underway to link more closely the protected area data files with those on threatened animals and plants, and, as noted above, we use a number of common programs and files on the computer (particularly those concerned with geographical location, and with bibliographies). Future developments will include the integration of computer mapping and map handling techniques.

National conservation databases are now being developed or planned in several countries, and CMC is already cooperating with a number of these. Working with such databases has the dual advantage that not only is much of our information coming from one source, but also that it can be sent to us in computer compatible form. Information on parks and reserves in both New Zealand and South Africa, for example, has been supplied on computer diskette, and most of the information on the subantarctic islands has also been supplied in this way. CMC is also starting to assist in the development of some of these databases.

Despite all these developments and the evident usefulness of CMC, the ability to carry out all of our tasks required ultimately depends on the information available, and our capacity to make use of that information. For outputs to be of most use to conservation planners at all levels, the data need to be both flexible and broadly based. This is a central aim of CMC's operation. Crucial to this aim is the maintenance of high quality, accurate information, and this is leading to the development of an ever broadening contact network. Currently the information is patchy, and much more work must be done in improving it. This work is under way.

THE WIDER IMPLICATIONS

As the World population continues to expand, and as development of available resources continues to increase, use and management of natural resources will in the future need to be much more effective, and integrated on an international scale. Effective management depends ultimately on knowledge, and the disseminaton of that knowledge, be it on management techniques, or on ecosystems and their management needs.

This knowledge can be, and is being, gleaned at the local level by scientists and conservationists throughout the world, but can be put to best use if it is gathered and disseminated not just at a local level, but also through a central office (facilitating, for example, the application of global arguments to local issues). If this is done through the framework of international organizations, then the results can in many instances be even more powerful and useful than if those same functions were performed independently at national or regional level. IUCN is aiming to provide such an international framework through its Conservation Monitoring Centre.

However, for conservation ideals to become more fully integrated into management and management planning on a global scale, information is required from a far wider range of disciplines than those normally associated with 'nature conservation'. The Global Environment Monitoring System (GEMS) was set up by the United Nations Environment Programme to "keep track of environmental trends, to be able to predict events and to provide decision-makers with sound information upon which to base environment action plans". GEMS are now in the process of establishing a Global Resource Information Database (GRID), of which CMC will be a part. GEMS is not an organization, but a programme, coordinating and directing existing talent and facilities, making use of organizations such as the World Health and Meteorological Organizations, the Food and Agriculture Organization, Unesco, and of course IUCN.

If GEMS is the hub of the wheel of organizations associated with the environment, CMC occupies a similar position with respect to organizations and government departments associated with nature conservation. The organization is involved, but this should not detract from the value, and indeed the necessity of the work. For many reasons our environment requires management; the key to successful management of the environment is information.

Contract Paper No. 2

International Inventory and Monitoring for the Maintenance of Biological Diversity

N. Mark Collins
Conservation Monitoring Centre

September 1986

Office of Technology Assessment
U.S. Congress

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International Inventory and Monitoring for the Maintenance of Biological Diversity

by

N. Mark Collins

IUCN Conservation Monitoring Centre
219c Huntingdon Road, Cambridge CB3 ODL, UK

SEP 23 1985

ABSTRACT

Biological diversity, inventory and monitoring are defined in the introductory material. The main international organizations involved in inventory and monitoring are described, with details of activities, their focus on biological diversity, databases, staffing, funding and level of US support. UNEP, FAO, UNESCO, IUCN, CMC, WWF, ICBP, COE and EEC are considered. The various constraints on the work of these organizations are described, including the present state of knowledge on biological diversity, technological and organizational matters. The storage and usefulness of data on biological diversity are summarized. Finally, suggested actions include improvement of links between taxonomic information and international databases; support of relevant US-based research programmes; encouragement of awareness and support of international organizations that monitor biological diversity, and more effective utilization of international databases.

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17 September 1985

1. INTRODUCTION

To give a context and rationale for the efforts by international bodies to measure, monitor and maintain biological diversity, a series of questions may be raised:

a) What is biological diversity?

b) How is diversity maintained, constrained and patterned in nature?

c) What impact is humankind having on biological diversity?

d) Why is this of international as well as national interest?

a) What is biological diversity? The concept of diversity varies at different ecological levels, within a community, between communities and across a landscape (Whittaker, 1977). At the level of a single community, ecologists distinguish between simple species richness, i.e. the total number of species within a community, and species diversity, a more complex measure in which numbers of species are integrated with their relative abundance. An example may serve to illustrate the difference: two savannas that each have 1000 ungulates of 10 species are equally species rich, yet one savanna with 100 ungulates of each species would be more diverse than another savanna with 910 animals of a single species and 10 each of the other nine. This distinction between species richness and diversity is of more than academic interest to environmentalists, for it must be recognised that maintenance of diversity is not simply a matter of preventing extinctions (i.e. preserving richness) but also of maintaining balanced and self-sustaining populations. The maintenance of diversity across landscapes is the main aim of protected area systems. This subject is covered by other authors in this series of OTA papers; here it will be discussed to some degree, but I shall mainly address biological diversity within and between communities.

b) How is diversity maintained, constrained and patterned in nature? The constraints on diversity are i) temporal (long periods of evolution, succession and regeneration lead to high diversity), ii) spatial (larger areas are more diverse), iii) abiotic (favourable climatic, edaphic, chemical and physical conditions promote diversity) and iv) biotic (plants and animals in communities develop cybernetic systems that increase diversity, but within the limits of other constraints). Humankind has now become a separate category of constraint, since through technological advance we are able to intervene and change the architectural, faunistic, floristic or genetic structure of any ecosystem by any combination of mechanisms i) to iv) above. The main patterns of diversity in nature are:

i) Species richness and diversity increase with proximity to tropical and equatorial latitudes; ii) diversity decreases with increasing altitude; iii) on islands, the number of animal species increases with island size and with proximity to a continent; iv) ecosystems that suffer severe limiting factors (high salinity, flooding, freezing) or acute events (hurricanes, fire) have reduced species diversity; v) intermediate disturbance of ecosystems can raise diversity; vi) in systems under human exploitation, species richness decreases as intensity of exploitation increases.

c) **What impact is humankind having on biological diversity?** People influence species diversity by exactly the same processes which work in nature, but at a greatly increased scale and intensity. Biological diversity is reduced relatively little by small communities of hunter-gatherers and slash-and-burn agriculturalists, but losses increase dramatically with growing human populations and the development of agricultural and industrial technology. In the early stages of disruption, diversity is reduced locally through changes in distribution and population balances of wild organisms. At more advanced stages, species disappear locally and the richness of communities declines as well as the diversity, but with the prospect of recovery by immigration. With chronic disruption, richness and diversity are permanently reduced as a result of worldwide species extinctions. Some 25,000 plant species (Huxley, 1984) and more than 1,000 vertebrate species and subspecies are now estimated to be threatened, yet these two categories of organisms represent only a small proportion of the species on our planet (see 3.1.). There is growing evidence that many thousands of invertebrates may also be at risk (Wells, Pyle & Collins, 1983; Collins & Morris, 1985). Extinction of species on this compressed scale would be without precedent in human history.

d) **Why is this of interest to international as well as national organizations?** Humankind is reliant upon biological diversity for aesthetic, ecological and economic reasons. The national perspective spreads through all three, but the international interest centres upon ecological and economic reasons. This is a result of the growing recognition of two central factors: a) international movements of commodities and technology can result in environmental effects far removed from the sources or from the consumer; and b) humankind now has the capacity to create environmental hazards on a global scale and within a single generation.

As much as two-thirds of all terrestrial species and the majority of endangered species are located in developing countries. Significant loss of species could directly affect human health and welfare locally, and even nationally, particularly in developing countries. For poor people in rural areas wild plants and animals are a source of food, traditional medicines and income. In some countries, tourism based largely on wildlife is a major source of foreign exchange. Worldwide effects of species loss could be felt in the fields of agriculture, industry and science, and on human health and welfare generally. Thus, there is a common incentive for developed and developing nations to prevent reductions in biological diversity.

Inventory and monitoring are the two key steps that facilitate corrective action in situations where humankind is at risk of causing, or has already caused, reductions in biological diversity. What precisely do these steps involve?

The term inventory implies basic survey and enumeration of species and their distributions. It is a process which can combine traditional biological survey with the most modern technology and sophistication. On the c hand, expeditions from the world's universities and scientific institutions are still engaged in furthering our knowledge of life on earth, while on the other the world's systematists and taxonomists are engaged in describing it in an orderly and universally understandable way. Classical taxonomy, using morphological, serological and biochemical data to classify organisms, is assisted now by cytotaxonomic (using chromosomes) and numerical (using mathematics) methods. There continues to be an acute need for inventory data, particularly from the tropical forests of the world, which have been little studied so far. Taxonomists are constantly faced with difficult decisions on where to set their priorities (see section 3).

Monitoring in the context of this paper means surveillance of the distribution and abundance of wild flora and fauna. The purpose of monitoring is to catalogue perturbations to wild species, assess the extent to which humankind is responsible, and promote corrective measures wherever necessary and possible. Monitoring is done in the knowledge that many wild species are already being affected by the processes and corollaries of human population growth development and technological advance, and that the degradation of natural processes must, overtly or covertly, run contrary to human welfare. Ideally then, a cybernetic system of information - analysis - corrective action - surveillance feedback loops will be developed, with human beings operating their control over natural processes in a responsible manner, and in the knowledge that human civilization is itself subject to global ecological processes.

2. INTERNATIONAL EFFORTS - THE ORGANIZATIONS INVOLVED

The scope of this report is limited to a consideration of the efforts being made by international organizations to inventory and monitor biological diversity. The main international organizations involved are UNEP, FAO, UNESCO, IUCN, WWF and ICBP (abbreviations are listed after the references). COE and EEC have mainly European regional interests. Each organization has its own perspective on diversity, and reasons for encouraging the study of diversity, but there are wide areas of overlapping interest. Through regular consultation and correspondence these organizations avoid duplication of effort and work towards similar goals. One of the main coordinating bodies is the Ecosystem Conservation Group, which holds regular meetings of representatives from UNESCO, UNEP, FAO and IUCN. These efforts at coordination are constrained by financial and material considerations, and there is still considerable room for further cooperation and inter-linking, particularly in the field of management and processing of biological and environmental data.

In addition to these international organizations, there is a growing number of national organizations taking an international perspective. It is beyond the remit of this paper to consider such organizations in any detail, but it is recognized that many of them make a major contribution to world knowledge of biological diversity. Indeed, to give full credit to such national organizations would require another major report. The world's older museums of botany and zoology play a fundamental role, and their contribution is acknowledged in Objective 6.1 of this report. In addition, some national conservation organizations, such as the U.S. Nature Conservancy, have important international programmes. The Nature Conservancy, well known for its "National Heritage Program", has developed on international wing that has already assembled a regional database on Neotropical fauna and flora, and country-level "Conservation Data Centers" for inventory and monitoring.

2.1 UNITED NATIONS ENVIRONMENT PROGRAMME (UNEP)

Main address: P.O. Box 30552, Nairobi, Kenya.

2.1.1. Mandate

The role of UNEP is to act as coordinator, catalyst and stimulant for activities, projects and programmes relating to the human environment.

2.1.2. Activities

Formed in 1972, UNEP is one of the units administered by the Secretariat of the United Nations General Assembly. UNEP itself is not operative, but it coordinates and stimulates a wide range of environmental projects in other organizations. Many of these projects are carried out by the operative specialised agencies of the UN, such as FAO and UNESCO, each of which has its own charter and membership, separate from the UN membership. Other projects are done by national and international organizations outside the UN system (e.g. MARC, IUCN).

Under its Environment Programme, UNEP has an assessment arm, Earthwatch, whose function has been to acquire, monitor and assess global environmental data. Earthwatch is now seeking to package the data it has gathered in an attractive and understandable form, as a service to key decision-makers in all fields concerning environmental management (see GRID, 2.1.4.).

Assessments by Earthwatch are applied by UNEP in its environmental management programme. This is divided into seven main areas of interest a) environmental aspects of human settlements; b) terrestrial ecosystems; c) environmental development; d) oceans; e) energy; f) natural disasters; g) environmental law.

2.1.3. Focus on biological diversity

At the heart of Earthwatch is the Global Environment Monitoring System (GEMS), an international effort to acquire, through monitoring, the data that are needed for the rational management of the environment. Monitoring may be carried out for a wide variety of purposes, but the main objectives of GEMS are the following:

a) to detect, monitor and analyse changes in the environment;

b) to study levels and trends of environmental indicators with a view to corrective action;

c) to check on compliance with established environmental quality criteria and standards;

d) to check on the efficiency of control systems and corrective measures;

e) to survey and study the effects of environmental changes, in particular on human health, food supply and natural resources;

f) to study the effects of human activities on the environment, so as to determine whether alternative patterns of activity would be more appropriate;

g) to collect time series of data on environmental variables in order to identify cause-effect relationships between them.

The current activities of GEMS are divided into five major programmes a) renewable natural resource monitoring; b) climate-related monitoring; c) health-related monitoring; d) monitoring of the long-range transport of pollutants; and e) ocean monitoring. These activities are coordinated from the GEMS Programme Activity Centre (PAC) in Nairobi, which, in the manner of UNEP itself, is not operational but works mainly through the intermediary of the specialised agencies of the United Nations System - most notably FAO, ILO, UNESCO, WHO and WMO - together with appropriate intergovernmental organizations such as IUCN. Hence, much of the international effort to inventory and monitor global biological diversity is well coordinated.

The GEMS programme on monitoring of renewable natural resources is central to the subject matter of this paper. The interests of GEMS are widespread, but to give some idea of UNEP's involvement in biological monitoring, three project examples will be described.

a) Tropical Forest Resources Assessment Project

In the 1970s GEMS developed and applied, through FAO, a system for inventory and monitoring of the forest cover in some tropical countries of West Africa (FAO, 1980). The methods included a combination of satellite and aerial imagery, aerial observations and ground-truth surveys. Similar methods are being applied elsewhere, first in Asia, then Latin America, and finally Africa - thus leading to a global monitoring network of national projects. In addition, as a background and baseline to future tropical forest monitoring, UNEP, in cooperation with FAO, has assessed the present state of tropical forest resources of the world at national, regional, and global levels. This assessment covers 76 tropical countries and includes information on natural forest, logged and cleared forest, secondary regrowth forest and plantation forest.

The assessment was based upon recent published and unpublished reports - local, national, and regional - which were spot-checked by satellite image analysis, the indicated rates of change being used to extrapolate the resource status to December 1980. Where no useful data existed, the forest resources were assessed by satellite image analysis alone. So far, regional summaries have been published for Asia, Latin America, and Africa (FAO 1981a, 1981b, 1981c). A short but very useful global summary is also available (GEMS, 1982). It is intended that this assessment will form the baseline against which future changes can be measured. Information from the assessment will form the basis of a tropical forest resources database, which will receive information from the various national monitoring programmes as they are developed. It is hoped later on to expand the monitoring and assessment activities to include subtropical and temperate forest resources. However, continuing global forest monitoring and assessment are seriously hampered by shortage of funds; GEMS is relying heavily on remotely sense data.

b) Ecological Monitoring Units (EMU)

During the last 12 years GEMS has developed a system for monitoring the life-support capacity and productivity of land - including climate, soils, plants and animals as well as humans and their activities - with the ultimate aim of ensuring optimum utilization of the natural resources. The methods involve sampling from three levels - space, air and ground (Gwynne and Croze, 1978). Monitoring can be done in the short-term, thus providing data on seasonal changes and variability. Repeated short-term monitoring is then the basis for long-term monitoring to establish trends in time.

A continuing pilot project on pastoral ecosystems monitoring in Senegal (with FAO) is being used to test and develop methods for rangeland conditions. In this way the practical development benefits that can accrue from an EMU can be demonstrated, heralding the time when these technologies may be put into widespread use. About ten countries in Africa are applying the method, as for example in Kenya, where the Kenya Rangeland Ecological Monitoring Unit (KREMU) has been operational for nine years and is an integral part of the Government's planning and development machinery.

With the recent drought and famine in the Horn of Africa there has been much discussion of predictive models and methods. On-the-ground sociological indicators (food prices, population movements) offer some advantages, but there is also enormous potential for widespread ecological monitoring by satellite across the Sudano-Sahelian zone. In the past, the remote sensing part of ecological monitoring has been done mainly by LANDSAT satellites carrying a number of imaging systems including radar (mainly for weather observations) and multispectral optical sensors (mainly for vegetation cover). The data are stored on magnetic tape, each tape comprising a scene covering an area 185 x 185 km. Each scene is recorded every 18 days. LANDSAT 3 produced data for "pixels" representing 79 m x 79 m, a relatively coarse resolution compared to airborne systems. LANDSAT 4 (launched in

1982) carried a "Thematic Mapper" with improved spectral (7 bands) and spatial (30 m) resolution. The system soon failed, however, and has been replaced by LANDSAT 5 with similar characteristics (launched in 1984) (Morton, 1984).

The LANDSAT satellites are now privately-owned systems, and although they will continue to provide invaluable information, a new generation of high altitude satellites put up by NOAA is expected to be of great value in providing early warning of environmental disasters. Two satellites carrying AVHRR systems (advanced very high resolution radiometers) have been put into orbit. These are basically coarse resolution weather satellites that give images in a 2400 km swathe, each satellite recording the earth's surface once per day. These images can be used to estimate vegetation biomass as well as weather conditions, and with coverage of the earth twice daily, close monitoring of drought areas is feasible.

c) Distribution and status of threatened species

GEMS has worked closely with IUCN to give the five-year-old Conservation Monitoring Centre clear-cut objectives and methods to use when assessing the status of species, species-groups and habitats. CMC has an interactive database that is described in detail in section 2.5. The data will eventually become part of GRID (see below).

2.1.4. Database coordination within GEMS

There is now a need to close the information loop by making environmental data easily available to both national and international environmental managers and decision makers, in order to pursue coordinated environmental monitoring and assessment. To provide access to the environmental databanks that are accruing from its inventory and monitoring activities, UNEP-GEMS has begun a two-year pilot project to set up a computerized Global Resource Information Database (GRID) (UNEP/GEMS, 1985). If successful, GRID will be the single most powerful tool for international inventory and monitoring, not only of biological diversity, but of other environmental parameters too. GRID will provide a centralized data management service within the UN system, designed to convert environmental data into information usable by decision makers. The main data-processing facility will be situated in Geneva, Switzerland, but it will be controlled from UNEP headquarters in Nairobi. Potential participants in the project, along with UNEP, are Canada Land Data Systems; Environment Canada; Environmental Systems Research Institute, USA; Department of the Environment, UK; IUCN/CMC; National Aeronautical and Space

Administration, USA; National Environmental Research Council, UK; and Prime Computer Corporation, USA.

GRID will have four main functions:

a) to centralize access to a number of environmental databanks;

b) to collate, integrate and analyse numerous environmental data sets for national and regional land-use planning and management;

c) to establish an analytical and data management base for a series of assessment statements on environmental issues;

d) to serve as a mechanism, especially in developing countries, for supplying national and international decision makers with analysed environmental data, appropriate technology for environmental data analysis, training in the use of the technology, and advisory assistance for upgrading existing capabilities.

When operational, GRID will provide data on a global, geographical basis on such resources as soils, vegetation cover, landscape and climatic features, protected areas, wildlife and livestock, human settlement, and many other project areas. It will emphasize cooperation with developing countries and UN agencies on a system-wide basis. The pilot phase of GRID will result in an operational system with preliminary results and trained practitioners. An evaluation would be expected at the end of UNEP's 1986/87 biennium, but the full value of GRID will emerge after several more years of operations (UNEP/GEMS, 1985).

2.1.5. Database hardware

The GRID system will consist initially of contributions of hardware and software. Already, computer systems have been secured, and ancillary equipment such as digitizers, line printers, plotters, terminals and image-processors are also included. As GRID grows, further units such as an array processor will be added.

2.1.6. Database software

A review of the hardware and software criteria for GRID took place in the UK in 1983 (Bie, 1983). The GRID mechanism must be able to integrate environmental data sets which exist in a variety of formats from a variety of sources, from satellites to field notebooks. The most fundamental common denominator is geographical location: most decisions refer to a place on the Earth's surface. Hence, the best way to build a workable database management system is to base it on a geographical framework.

Nine general purposes for GRID emerged from the UK meeting:

a) inventory management

b) status reporting

c) monitoring of change

d) scientific research

e) forecasting

f) action planning

g) policy development

h) resource allocation

i) development action evaluation

These nine areas can be grouped to form two complementary systems that are envisaged for the pilot phase:

a) a global database system, which will consist of spatially extensive data and would be used to support integration of selected global data, ongoing monitoring and reporting of change, and forecasting of future change. It provides a base for the planning of focused inventory efforts, and a base for plans and policies regarding protection and management of environmental resources;

b) an analytical system which will focus on investigations of particular interest to UNEP. These could include regional, national or specific project or topic studies that UNEP would provide assistance in performing (e.g. environmental impact assessments, development planning or basic scientific research on selected topics).

There is no question of forcing the world's environmental data sets into just one analytical software system; there are already too many geographical information systems in operation to realistically expect an "industry standard" to take hold. Consequently, compatability will have to be achieved through the exchange of data files. It is envisaged that in practice the two types of application could exist within the same project, sharing data, data processing functions, staff and other resources.

2.1.7. Staffing and funding

According to their 1984 Annual Report, 177 professional staff are employed by UNEP (UNEP, 1985). About four professional staff are employed under GEMS (Croze, 1984).

The Environment Programme of UNEP/GEMS derives its funds from an annual assessment by member states. This assessment is not based on GNP; the levels of funding in any one year are unpredictable, and formalized only at a late stage. The following Table shows allocation of UNEP funds, 1984-85:

Budget lines	Allocation (%)
Environment & development	11.27
Environmental awareness	17.05
Earthwatch	12.14
Oceans	10.95
Water	4.28
Terrestrial ecosystems	15.05
Desertification	9.38
Health & human settlements	10.73
Arms race & the environment	0.57
Regional & technical cooperation	8.57
Total fund programme activities	$53.5 million

Total contributions paid or pledged to UNEP for 1984 amounted to $29.46 million (UNEP, 1985). The highest levels were in 1979-80, when $31.90 million dollars were contributed in each year. The UNEP GRID project has an estimated total cost of $2,479,000, of which $379,000 is to be paid by UNEP. This money has to be found over and above the usual donations.

2.1.8. Level of US support

In 1984 the total contribution from the USA to UNEP was $9,987,188. Funds to UNEP are channelled through the UN Secretariat in New York. Up to 80% of GEMS work is carried out by the specialised agencies of the UN, hence any change in US support to those agencies (e.g. UNESCO - see 2.3.6.) has a knock-on effect in the UNEP/GEMS programmes. The US is supplying substantial equipment (on loan) and services to GRID, but so far no cash has been donated.

One of the most severe problems at UNEP/GEMS is the shortage of technical staff. It is extraordinary that a system so broad in its concept, so wide-ranging in its projects, and so important in its work, can be administered by a staff of four. One significant way in which the US could assist UNEP/GEMS would be to second from US institutions technical staff knowledgeable in one or more of the programme areas listed under 2.1.2. above.

2.2. FOOD AND AGRICULTURE ORGANISATION (FAO)

Main address: Via delle Terme di Caracalla, 00100 Rome, Italy.

2.2.1. Mandate

FAO is the United Nations specialised agency responsible for data synthesis, analysis and strategic planning in the fields of agriculture, silviculture, fisheries and related subjects associated with the provision of the basic needs of human beings. In common with other UN specialised agencies, FAO has its own charter and membership.

2.2.2. Activities

FAO activities are very broad-based and will not be discussed in detail since most are irrelevant to this paper.

2.2.3. Focus on biological diversity

FAO's perspective in conserving biological diversity is based on the need to maintain sources of genetic material for sustainable exploitation by humankind. Such materials include organisms whose wild populations are harvested (tropical forest trees, fish, whales, crustacean and molluscan seafoods), wild organisms whose relatives are now domesticated in the service of humankind (agriculturally useful plants, wild relatives of domestic mammals and birds), and the wide variety of breeds of agricultural crops and domesticated animals, only a small proportion of which are in general use. Much of FAO's effort goes into ex situ conservation, which is outside the scope of the OTA report. Some brief outlines of FAO interests which relate to in situ conservation may be cited.

a) Farm animals

In 1980 FAO entered into consultation with UNEP on Animal Genetic Resources, providing the first international focus on this important subject (FAO, 1981). An action plan was prepared, and funding for implementation provided by FAO and UNEP. The objectives are:

i) to harness the (farm) animal genetic resources of developing countries in improved management programmes to enhance the production of food, fibre and animal power; and

ii) to conserve, in the preservation sense, those genetic resources that are in danger of being lost (Griffiths, 1984).

FAO's perspective in conserving genetic resources in farm animals is an interesting one. It ranges from the cryogenic storage of fertilised ova and semen from farm animals, to conserving in situ those relatives of domesticated mammals and birds which are to be found in the wild. In this latter respect it supports expansion and improved management of national parks and reserves (FAO, 1984).

Amongst other things, the FAO/UNEP Technical Consultation recommended that FAO/UNEP assist in the development of a database for livestock resources in member countries, and in the coordination of these at regional levels (FAO, 1981). Progress in achieving this aim was outlined in papers presented at a joint FAO/UNEP Expert Panel Meeting in October 1983 (FAO, 1984). Following one-year pilot trials in Africa (IBAR, ILCA), Asia (SABRAO) and Latin America (ALPA) (Hodges 1984, 1984) to identify methodologies for the preparation of data for the bank, a further Expert Consultation on the "Methodology for Animal Genetic Resource Data Banks" was held in Rome, 17-21 June 1985. Descriptor lists were adopted at this meeting to define the parameters of animal production which were to be stored in the database and recommendations were put forward for the establishment and operation of a regional databank in each of the four developing regions. One of the uses of these databanks is to identify those species and breeds which are most endangered so that recommendations can be formulated for their conservation. The bulk of the data refers to domestic livestock but coordination with IUCN was urged (Hodges in press) promote the conservation of related wild species, the majority of which are threatened. Further information may be found in FAO (1984).

b) Plant genetic resources (mostly *ex situ*)

Accessibility to plant genetic resources at the major gene banks is being carefully studied by FAO, with a view to the establishment of an international gene bank and the drafting of an international convention on plant genetic resources. The adoption by the FAO Conference, in November 1983, of an International Undertaking on Plant Genetic Resources was an important move towards developing a coordinated network of national, regional and international centres to hold collections of genetic resources of important plant species for the benefit of the international community. To implement this, FAO has established a new Commission on Plant Genetic Resources.

In 1983, UNEP initiated preparations for a survey of gene banks in Africa, Asia and Latin America with the aim of identifying those which store plant genetic resources and ascertaining the extent to which they are collaborating with the network of gene banks developed by the International Board for Plant Genetic Resources (IBPGR). IBPGR, supported by UNEP, initiated in 1983 activities for the exploration and collection of crop plant genetic resources in Madagascar, Sri Lanka and Uganda, to complement earlier collections which covered Benin, Kenya, Malawi, Somalia, Tanzania, Yemen, Zambia and Zimbabwe. The material collected was deposited in various gene banks, including those forming part of the network housing the World Base Collection co-ordinated by IBPGR (IBPGR, 1984).

c) Forest Resources Assessment Project (see 2.1.3).

2.2.4. Level of US support

Specific information on this topic has not been obtained. In the UN list of scales of contributions by nation members, the US remains at 25% for 1986-7. This is assumed to be the level of US support to FAO.

2.3. UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION (UNESCO)

Main address: 7 Place de Fontenoy, 75700 Paris, France

2.3.1. Mandate

Here I shall consider only the "Man and the Biosphere" Programme of UNESCO, whose purpose is to establish the scientific basis necessary for land use planning and for the management of the resources of the biosphere in harmony with nature (M'Bow, 1981).

2.3.2. Activities

The Man and the Biosphere Programme was launched by UNESCO in November 1971. It had its origins partly in the International Biological Programme, the first major international venture in biological research. Now over 100 countries are engaged in a common effort on some 1000 applied research and training projects involving more than 10,000 scientists and technicians. MAB follows a fundamental precept of UNESCO: that science and technology, to serve human progress more fully, must be integrated into each country's culture. In this way the research will be more likely to correspond to local needs and priorities for land use (Di Castri et al., 1981). The MAB Programme is almost totally decentralized, each activity being carried out directly by the participating countries, linked only by a small MAB secretariat in Paris.

2.3.3. Focus on biological diversity

Priority areas for the MAB programme have emerged as:

- a) humid and sub-humid tropical zones
- b) semi-arid and other marginal lands
- c) urban systems
- d) conservation linked to development

All of these areas contribute vital baseline data to the global pool of information on biological diversity. However, by the very nature of the MAB organization, and the diversity of its approach, there is a lesser degree of comparability of data than in a more narrowly focused programme (Di Castri et al., 1981). MAB cannot be said to be involved in international inventory and monitoring in a coordinated way, and yet the contribution to these subjects is very substantial indeed.

One particularly significant contribution is the Biosphere Reserve concept, based on the in situ, long-term conservation of sites representative of major ecosystem types (for an assessment of protected area systems, see OTA paper in this series by Jeremy Harrison). In the context of the present paper it may be noted that some countries have used the Biosphere Reserve concept to develop international cooperation in the field of environmental monitoring. For example, the USSR is cooperating with the USA under the bilateral agreement on Cooperation in the Field of Environmental Protection (signed by Nixon and Brezhnev). Monitoring of biological diversity is a part of the overall environmental monitoring programme (Sokolov, 1981). UNEP/GEMS is closely linked with this type of cooperation and is actively encouraging its extension (Croze, 1984). Objective 5 of the Action Plan for Biosphere Reserves (Anonymous, 1984) addresses the need to develop monitoring activities in Biosphere Reserves, thus linking with GEMS/GRID. A basic methodology for inventory and monitoring in Biosphere Reserves is being developed by the US-MAB Directorate (MAB Project 8 - Bill Gregg, Parks Service) in association with the Smithsonian and other US institutions.

In cooperation with the MAB programme, the International Union of Biological Sciences (51, Boulevard de Montmorency, 75016 Paris, France) has declared a Decade of the Tropics programme. The two programmes will include a series of activities for the promotion of comparable studies in tropical terrestrial and aquatic ecosystems, including a major component on species diversity (Solbrig and Golley, 1983). Two important parts of this component are a) the development of a reasoned evaluation of the importance and significance of species diversity in the tropics, and b) an investigation into standardised methodology for basic research on the subject (Maury-Lechon, et al., 1984). No compilations of data have been achieved as yet and hence the programme will not be described in further detail. However, the effort by IUBS to coordinate research into biological diversity has the potential to provide a link between the wide variety of studies being carried out in Biosphere Reserves, and the international efforts to inventory and monitor biological diversity being made by UNEP and IUCN. The U.S. Academy of Sciences proposed at the recent IUBS General Assembly (September 1985) that IUBS should greatly expand its initiative on biological diversity.

2.3.4. Staffing and funding

As stated, MAB is decentralised, with only a small secretariat of about ten people in Paris. Among the field projects, perhaps 30% would have existed regardless of MAB; 60% have been influenced by MAB; and 10% owe their existence to the approach and support of the MAB programme. Funding for research and training comes mostly from national sources. Some outside support, especially for developing countries, has come through UNESCO and UNEP and national aid agencies (Di Castri et al., 1981).

2.3.5. Future developments

International Biosphere Reserves are a sound idea, but unfortunately they are not yet functioning as a network with a flow of information between them (Croze, 1984). Basic questions need to be formulated before answers can be sought, and in this respect the IUBS programme (see 2.3.3.) is fulfilling a useful function. Extensions of monitoring programmes within Biosphere Reserves, and integration of data into the GEMS/GRID programme would be highly advantageous. In due course, the system could provide a constant flow of advice and analysis on global environmental questions, giving decision makers the best possible information on which to base their actions.

2.3.6 Level of US support

As a specialized agency of the United Nations, UNESCO has its own charter and membership. In recent years some members, notably the US, UK, Netherlands, Switzerland, Denmark, F.R. Germany and Japan demanded reforms, mainly to return UNESCO to its original mandate of 1945, which was to combat illiteracy and promote international understanding through the free exchange of ideas and knowledge. Critics say the organization has become heavily political, in particular by supporting collective national rights against those of the individual, and by calling for a "new world information order" that assigns a political role to the press. In addition, UNESCO has been accused of mismanagement.

The US formerly paid 25% of UNESCO's budget, but this was withdrawn from the beginning of 1985. The MAB programme was badly hit, making adminstration very difficult. Nevertheless, the opportunity remains for US agencies to make separate contracts with particular aspects of UNESCO's work. Every possible avenue for continuing to support MAB from US funding deserves thorough exploration. The MAB programme is too large, too successful and too important to be allowed to suffer setbacks for financial reasons that are not directly related to the MAB programme itself.

2.4. THE INTERNATIONAL UNION FOR CONSERVATION OF NATURE AND NATURAL RESOURCES (IUCN)

Main address: World Conservation Centre, Avenue du Mont-Blanc, CH-1196, Gland, Switzerland

2.4.1. **Mandate**

To promote scientifically-based action for conservation, including sustainable use of living natural resources.

2.4.2. **Activities**

IUCN is a network of governments, non-governmental organizations, scientists and other conservation experts, joined together to promote the protection and sustainable use of living resources.

Founded in 1948, IUCN now has a membership which includes 57 governments, 123 government agencies, 292 national, non-governmental organizations, 23 international NGOs and six affiliates in over 100 countries. Its six Commissions consist of more than 700 experts on threatened species, protected areas, ecology, environmental planning, environmental policy, law and administration, and environmental education.

IUCN:

a) monitors the status of ecosystems and species throughout the world;
b) plans conservation action, both at the strategic level through the World Conservation Strategy and the programme level through its programme of conservation for sustainable development;
c) promotes such action by governments, intergovernmental bodies and non-governmental organizations;
d) provides assistance and advice necessary for the achievement of such action.

The Union's members meet every three years in General Assembly to elect the President, Council and Commission Chairmen. A three-year umbrella programme is adopted, consisting of a set of programmes covering individual areas and topics. The programme is administered by a small secretariat of scientists and professionals under the Director General.

IUCN has close working relations with many members of the United Nations system. IUCN provides the secretariat of the Ecosystem Conservation Group (UNEP, FAO, UNESCO, IUCN), which coordinates action in this field. The Union cooperates with a number of other intergovernmental bodies, and has an especially close working relationship with the World Wildlife Fund (see below).

There are three Centres which are also part of IUCN, i.e. the Conservation for Development Centre (also in Gland), the Conservation Monitoring Centre (Cambridge, UK) and the Environmental Law Centre (Bonn, F.R. Germany).

2.4.3. Focus on biological diversity

The term biological diversity means, to a large extent, the same as the "Nature and Natural Resources" in IUCN's title. Maintenance of the diversity of life on earth is the central aim of all of IUCN's work. It is the only truly international organization with this broad aim, and is unique amongst international organizations in having a voting and policy-making membership that includes not only governments, but NGOs too. Having said this, there are particular aspects of IUCN's structure that focus on biological diversity, in particular:

a) the IUCN Commissions for Species Survival, Ecology and National Parks and Protected Areas; and

b) the IUCN Conservation Monitoring Centre (CMC).

Because CMC is in a separate location from the main headquarters, and also because the work of CMC is particularly pertinent to this report and needs to be covered in detail, CMC is considered in a section of its own (see 2.5).

2.4.4. The IUCN Commissions

The work of the Commission on National Parks and Protected Areas (CNPPA) will be fully described in the OTA paper by J. Thorsell and will not be repeated here.

The Commission on Ecology (CoE) includes about 160 members in over 20 Working Groups. Specialities of these groups range from remote sensing to pollutants, mangroves to mountains. Their aim is to use ecological insights to encourage practical programmes of land management and nature protection. To this end, a number of documents have been published as supplements to The Environmentalist. CoE draws attention to community and landscape diversity by publications such as those on mangroves (CoE, 1983) and ocean trenches (Angel, 1984).

The Species Survival Commission (SSC) is the largest of IUCN's commissions, with about 150 full members and over 1200 scientists and other experts organized into more than 80 specialist groups. This is a volunteer network that serves as a primary source of the scientific and technical information required for the conservation of threatened fauna and flora. The SSC works to prevent extinctions, thereby maintaining genetic diversity and contributing to the conservation of ecosystems and natural resources. The Specialist Groups (SG) are of varying size and focus, ranging from the species level (e.g. Hippo SG) through groups of species and genera (e.g. Pigs and Peccaries SG) to families (e.g. Canid SG), orders (e.g. Odonata SG) and even phyla (e.g. Mollusca SG).

The terms of reference of the OTA paper, i.e. technologies to maintain biological diversity in situ, might not immediately appear to warrant consideration of the Commissions. This would be a mistake because the acquisition of ecological, faunistic and floristic data for monitoring and inventory depends ultimately on field scientists. Indeed, the ability to compile and analyse data from a wide range of sources is one of the major constraints on the success of international organizations that are interested in the maintenance of biological diversity. Moreover, the Commissions are the policy-makers of IUCN, and have the potential to be operative agencies for implementing conservation effort. In practice, however, the mechanisms for effecting conservation quickly are still being developed (see Section 5).

2.4.5. Future development of the Commissions

IUCN has been very successful, with the financial help of UNEP and WWF, in organizing such an international network of scientific authorities, all interested in the maintenance of biological diversity. As is so often the case, however, the successful construction of the Commissions has shifted, rather than removed, the information and activities bottlenecks. The Commissions, particularly SSC, are currently under-utilized as a source of technical advice. The mechanics of utilizing the network more effectively are currently under review. The IUCN staff working with each commission include only one Executive Officer plus secretarial support. There are plans to add a Species Programme Officer to SSC, who will be responsible for matching data from SSC with the needs of WWF, IUCN, UNEP, governments and other potential users, as well as stimulating the specialist groups. A major area of development in the future will be the building of closer links between all the commissions and CMC. Already the Specialist Groups of SSC provide considerable information to CMC, for inclusion into the computer database, the Red Data Books and other documents (see section 2.5), and CNPPA provides data for protected area handbooks.

2.4.6. Staffing and funding

IUCN has a small secretariat of 30-40 staff, not including the staff at the three IUCN Centres. The funding of the IUCN Secretariat for core and project activities in 1985 may be broken down as shown below. It is anticipated that IUCN's income will rise to about $5.25 million by 1987. Even so, these are very small sums with which to tackle the growing global problems that are the mandate of IUCN.

	%
Membership	25.8
World Wildlife Fund	26.0
UNEP	8.1
UNESCO	2.0
SIDA-tropical forest office	2.7
Project Management fees	9.6
Sponsors of CDC	7.7
Contributions to CMC	7.6
Publications	1.4
Interest	2.0
Others	7.1
Total amount	$ 3.91 million

2.4.7. Level of US support

The USA is not a state member of IUCN, but three government agencies and 49 non-governmental organizations are members of the Union. The three government agencies are the National Oceanic and Atmospheric Administration (NOAA, Dept. of Commerce), the Forest Service (Dept. of Agriculture) and the Department of the Interior (corresponding agencies: National Parks Service and Fish and Wildlife Service). The NGO members include all the major conservation and environmental organizations within the USA.

There are plans to open an IUCN office in Washington D.C. within the next few years. The office will be in close communication with IUCN HQ, CMC and CDC, and will greatly improve IUCN's operations in the New World. The US administration and its agencies are invited to advise and support IUCN in this initiative.

2.5 THE IUCN CONSERVATION MONITORING CENTRE (CMC)

Main address: 219c Huntingdon Road, Cambridge CB3 ODL, UK; Threatened Plants Unit: c/o The Herbarium, Royal Botanic Gardens, Kew, Richmond, Surrey, TW9 3AE, UK).

2.5.1. Mandate

Gathering, analysing and disseminating information on nature conservation worldwide as a service to governments and the conservation and development communities.

2.5.2. Activities

Global nature conservation data are collected by specialist staff from published and unpublished literature and via an international network of contacts, many of them members of the IUCN Commissions. The information is critically assessed, and stored in three ways: (a) computer data files containing coded, summarized data, (b) computer text files, containing expanded information in a more flexible format, (c) paper files. Outputs are books, specialist publications and reports. Data held can be broadly divided into four categories: flora, fauna, protected areas and wildlife trade. CMC is divided into six units, the responsibilities of which follow these four divisions, plus computer services and publications.

2.5.3. Focus on biological diversity

The two CMC units dealing with flora and fauna are concerned entirely with the subject matter of this paper, i.e. inventory and monitoring of global biological diversity. The choice of priorities for work within this vast field is ascertained with reference to the mandate of IUCN, i.e. the conservation of nature and natural resources. The focus of work is at the species level, but with due regard to populations, communities and ecosystems.

2.5.4. Database hardware

A Wang VS80 is located at the Kew office, with 512Kb main memory and 750Mb on-line disk storage. A Wang OIS 115 multi-user WP system is located at the Cambridge office. The two are linked by a Wangnet networking system, allowing remote logons to the VS, and giving the OIS access to the VS disk storage. A total of 17 terminals are currently in use, of which 15 can access the VS80 and nine the OIS-115. A British Telecom CCITT V26 synchronous modem (2400/1200 baud) is installed, and mainly used for communication with IUCN headquarters, Switzerland. At Cambridge there is also a Wang PC-XC2 with 256Kb main memory, dual floppy disk drive, with interfacing capacity with the VS and the OIS. At Kew a BBC Model B micro-computer with Torch dual floppy disk drive is available, interfacing with the VS via a RS232.

2.5.5. Database software

Software is written in COBOL. Unfortunately, there is no commercially available database management software for the VS series that can adequately cope with CMC data-handling requirements. Word-processing documents can be written and accessed under programme control using Wang software.

2.5.6. Database inputs

The main input modes for the CMC computerized database are as follows:

data files:

a) geographical skeleton of world political and biogeographical areas;
b) taxonomic skeleton for flora and fauna, including synonyms, etc.;
c) species: taxonomic, distribution and conservation status, including occurrences of taxon in collections (i.e. botanical and zoological gardens),
d) protected areas: size, level of protection, biogeographical province, and other summary data;

e) wildlife trade: type and quantity of shipments of threatened taxa and their products imported and exported under CITES;

text files:

a) species data: these include details of the status, distribution, ecology and conservation requirements of the taxon;

b) protected areas: physical and biological description of the area, level of protection, administrative details;

c) national summaries: protected areas and legislation in each country; status of threatened plants and their protection in each country;

d) critical habitat sites: coral reefs; wetlands; etc.

Numerous other subjects are covered in text files.

The approximate total numbers of computer database entries as of January 1985 were as follows:

a) global geographical units: 600

b) flora: 500 families, 16,000 genera, 30,000 taxa, 19,000 records for 4,000 threatened taxa in cultivation among 300 botanic gardens

c) fauna: 17,000 taxa, 60,000 taxon distribution records

d) protected areas: 9,000

e) wildlife trade shipments: 210,000.

Data are being continuously accumulated in each of these categories, but at varying rates. The computer database entries are supported by approximately 6,000 text files (data sheets), mainly on individual species and sites. These are also on the increase, and are individually updated as necessary.

IUCN encourages wide use of its standardized categories to indicate the degree of threat to species (e.g. Endangered, Vulnerable), and the level of management for protected areas (e.g. Strict Nature Reserve, National Park).

2.5.7. Database outputs

CMC supplies information in the form of books, specialist publications and reports. CMC also undertakes contracts to provide detailed data on request. Major outputs include Red Data Books (Wells, Pyle and Collins, 1983; Lucas and Synge, 1978; Groombridge and Wright, 1982, Thornback and Jenkins, 1982; Collins and Morris, 1985; Collar and Stuart, 1985); Protected Area Directories (IUCN, 1982); conservation site directories and reports; threatened plant and animal lists; UN List of National Parks and Equivalent Reserves; preliminary environmental profiles of individual areas (by request); comparative tabulations of transactions under CITES; and analyses of wildlife trade data for individual countries and taxonomic groups plus a number of scientific and technical documents. CMC issues the periodicals 'Traffic Bulletin' and 'Threatened Plants Newsletter'.

2.5.8. Uses and applications of the database

Governments, aid agencies, development banks, conservation organizations (especially IUCN members), other international organizations, scientists, the news media and commerce all use the database. CMC is IUCN's contribution to UNEP/GEMS. CMC's clients include the World Bank, UNESCO, FAO, EEC, OECD and CITES Secretariat.

CMC tries to cooperate with all national and regional databases on conservation. Electronically stored data have been exchanged with many other bodies, including the US Fish & Wildlife Service, Brookhaven Laboratory, and NASA. The capability of exchanging data with UNESCO, Paris has also been tested (protected areas).

2.5.9. Staffing and funding

Between 35 and 40 staff are employed at CMC. At present they are apportioned as follows:

Director	1	Administration	3
Threatened animals	9	Threatened plants	8
Protected areas	4	Wildlife trade	8
Computer services	3	Publications	2

The total budget of CMC for 1985 is £508,000 (equivalent to $660,400 @ S1.30 = £1). This is obtained as follows:

Core and core-related funding	
IUCN/WWF (International) core	20%
UNEP (GEMS)	30%
CITES	7%
Grants	12%
Contracts for services	31%

CMC's budget, accomodation and computer hardware are very modest for the scope of the work undertaken.

2.5.10. Future developments

Hardware: to further develop data-processing applications a hardware upgrade is planned. This is likely to entail moving to computers with a wider range of software, a friendlier software development environment, better communications options and good graphics capability. CMC is seeking sponsorship for this major development.

Software: (a) development of existing geographical and taxonomic databases into a geographical information system using graphics; geo-referencing of species data will be essential for compatability with GRID; (b) further refinement of database field structures, and of the quality of the stored data (e.g. introducing a habitat coding system), (c) development of a database on conservation projects, in conjunction with WWF, (d) development of databases on critical habitat sites (e.g. coral reefs, wetlands, islands). (e) development of capability to provide remote access to the database by outside users; (f) creation of a standard software system to be used in setting up national or regional conservation databases.

Data sources: to improve and devise methods of accessing biological inventory material quickly and efficiently. In theory it should be possible to access any data on species and distribution that is stored electronically. In practice, limitations of staff time and computer capacity have prevented accession of such material to any large degree.

Data analysis: the CMC database now contains sufficient data to present opportunities of analysis using indicator groups of wildlife. Pilot projects to assess centres of endemism and richness, and effectiveness of protected area coverage, are in progress.

Accomodation: CMC is actively seeking financial support for a new purpose-built office in Cambridge at an estimated cost of £1 million. US support for this initiative is invited.

2.5.11. Level of US support

It is difficult to assess what proportion of the core-related funds has its origin in the USA. However, it is likely to be substantial, in keeping with the levels of contribution made by the USA to the UN agencies. In the current year none of the funds received in the form of grants and contract payments for services have come directly from the USA, although funds for some contracts with international bodies undoubtedly had a US origin in part.

The USA administration, operating through its agencies, has many opportunities to enhance the work of CMC. Much could be achieved by utilizing the CMC database under contract agreements. However, the new generation of technology to monitor biological diversity will require a capital investment of several million dollars, to pay for new buildings and computers.

2.6 WORLD WILDLIFE FUND (WWF)

Main address: WWF-International, World Conservation Centre, Avenue du Mont Blanc, CH-1196, Gland, Switzerland

2.6.1 Mandate

To raise funds and create awareness and support for conservation worldwide.

2.6.2 Activities

WWF is an international foundation formed in 1961.

WWF-International works closely with IUCN and shares offices in Gland. WWF also has 26 national organizations, each of which carries out its own projects, but also contributes to the general fund of WWF-International. Programme formulation and execution at WWF-International is carried out in close cooperation with IUCN, and has therefore been adequately summarized in section 2.4. There is one important exception to this generalisation, and this concerns the operations of WWF-US (address: 1601 Connecticut Avenue NW, Washington, D.C. 20009, USA).

WWF-US is so large that it plans and implements most WWF projects in the Western Hemisphere. Furthermore, WWF-US plans to undertake more activities on an international scale (WWF-US, 1985). In these undertakings WWF-US is participating in joint planning with IUCN and WWF-International.

2.6.3. Focus on biological diversity

WWF-US takes the view that when directions for conservation action are unclear for lack of scientific information, it is incumbent upon WWF-US to stimulate, fund or even conduct the necessary research. This need for an adequate scientific basis for conservation requires investigation of two types: biological inventory and ecosystems-orientated research (WWF-US, 1985). Accordingly, WWF-US perceives a role for itself in helping institutions of systematic biology to document the variety of life on earth, particularly in poorly known tropical regions. Already, WWF-US has initiated numerous research programmes in Central and South America, notably the critical size of reserves experiments undertaken at Manaus, Brazil. Although these projects are mainly for inventory, sometimes with a degree of monitoring, WWF-US does not have the database and monitoring facilities sponsored by WWF-International at the IUCN Conservation Monitoring Centre (see 2.5). In its funding of WWF-International, WWF-US ties some money to supporting CMC.

It was considered necessary to give this background to WWF activities in order to give perspective to international funding of biological inventory and monitoring. However, since WWF-International does not itself undertake these activities, except in the US office, which is a national not international body, no further details of staffing or funding will be given here.

2.7. INTERNATIONAL COUNCIL FOR BIRD PRESERVATION (ICBP)

Main address: 219c Huntingdon Road, Cambridge CB3 ODL, UK

2.7.1. Mandate

ICBP is a federation of over 300 national (and some international) organisations in 100 countries, concerned about the conservation, management and wise utilization of wild birds and their habitats.

2.7.2. Activities

ICBP

a) monitors the status of the world's birds and their habitats;

b) promotes public awareness of threats to birds, their ecological importance and value as environmental indicators;

c) carries out priority projects, advocating and implementing conservation measures where they are most needed.

2.7.3. Focus on biological diversity

Although certain areas of the world still require bird inventories, most species are now known and scientifically described (as is the case for mammals, except bats). The emphasis of ICBP and other ornithological organizations is on monitoring their status and taking action to protect habitats and species.

ICBP takes responsibility for ornithological aspects of IUCN's activities and shares the IUCN database at CMC, Cambridge (see 2.5.6). All species of threatened birds are entered into the data files (some 600 species) and there are hopes that all birds will eventually be included on the computer databank. ICBP's text files at Cambridge are very extensive, and unparalleled at the international level.

In 1982 ICBP adopted "Island Management" as one of a number of principal themes in its conservation programme. ICBP is in the process of establishing an Oceanic Islands Database to identify areas where urgent conservation action needs to be taken to safeguard numerous threatened island endemic bird species. The initial target is to collect details about the 160-plus islands which support endemic species of birds, especially those under 20,000 sq. km in area. CMC will be cooperating in this project when funds have been located.

Another principal theme of ICBP is the promotion of inventories of all areas of importance for birds. In 1985, these inventories comprised information on 964 sites in the ten EEC countries according to guidelines given in the EEC Birds Directive of April 1979; on some 775 sites in the 21 member states of the COE according to a first set of criteria derived from the Bern Convention; an accumulating database on areas in Africa utilised by Palaearctic migratory birds (175 sites in 35 countries identified to date); and initial phases of a database on tropical forest areas important for birds, especially centres of species endemism (Indonesia, Thailand, Madagascar and much of tropical Africa have been reviewed so far). In addition, ICBP maintains a project register which includes details of some 120 on-going ICBP projects, and a coded index of over 1000 international bird conservation issues and action recommendations taken from ICBP Technical Publications, Red Data Books, Study Reports and other sources, such as network correspondence. This register allows regional or country-based bird conservation priority profiles to be drawn up rapidly.

ICBP has 16 Specialist Groups, which serve as the bird groups of the IUCN Species Survival Commission (see 2.4.4. et seq.). These SGs are a permanent, worldwide network of experts who advise ICBP. ICBP also has Task Forces, which are temporary groups formed for a specific job to be completed by a deadline. Task Forces are backed up administratively by the Secretariat. They may deal with problems of single species, communities, habitats, ecosystems, regions or more general issues. As is the case for the IUCN/SSC, the organizational framework and methods of operation of ICBP can be viewed as a form of technology towards the maintenance of biological diversity.

2.7.4. Database hardware and software

The main threatened species database is shared with CMC and is based on a Wang VS 80 and OIS 115 (see 2.5.4, 2.5.5.)

The islands database, European Important Bird Areas Information and other inventories are stored on an IBM Displaywriter operating Reportback software; much of this material will soon be transferred to a more powerful system using an IBM PC-XT probably supported by dBASE III software. The coding system is generally compatible with that used by CMC, so these databases form an integral part of the wider activities of IUCN and ICBP in documenting the worldwide status of species and habitats.

2.7.5. Database inputs

Inputs for the species database are described under 2.5.6. Inputs for the other databases are extensive, and include general geographical data, physical conditions, biological attributes (including non-bird groups), habitat codings, conservation factors, land-use patterns and key references.

2.7.6. Database outputs

ICBP supplies information in the form of Red Data Books (e.g. Collar and Stuart, 1985) Study Reports (e.g. Phillips, 1985), and the Technical Publication series. Outputs from the EEC and COE databases are published only at the discretion of the respective international authorities.

2.7.7. Uses and applications of the database

ICBP's databases are employed mainly in the following ways:

a) programme planning and project identification, including production of simple statistical information;

b) servicing membership requests for specific types of information;

c) providing international and national governments with lists of important sites and/or threatened species;

d) to enhance implementation of wildlife legislation relating to birds, e.g. CITES, Ramsar, Bern and Bonn Conventions.

2.7.8. Staffing and funding

The international Secretariat in Cambridge has a small professional staff comprised of:

Director	1	Assistant directors	3
Administration	3	Research and monitoring	4
Computer services	1	Publications	1
Project assistants	2		

Secretariat income for 1984 was £165,510 (equivalent to $215,163 at $1.30 = £1), and may be broken down as follows (ICBP pers. comm., 1985):

Income from the membership	30%
Foundation grants	34%
Interest and $ exchange gains	35%
Others	1%

2.7.9. Future developments

In July 1985, ICBP appointed a Conservation Data Officer to assume responsibility for hardware and software development in the Secretariat, and to liaise with national member organisations also holding computer databases e.g. RSPB, NCC, NAS. Existing databases will be redesigned to allow relational integration and searches, and important gaps in knowledge will be systematically filled. Islands, Forests and later Wetlands will be core ecosystem-related databases, while a taxonomic database of species and their country by country distribution and status is envisaged when resources allow.

2.7.10. Level of US support

Grants and donations for ICBP's Secretariat operating fund in 1984 may be broken down as below (ICBP pers. comm., 1985). The average exchange rate in 1984 was taken as US$1.35 = £1). In addition, £139,700 ($178,800) was received earmarked for projects.

ICBP has a Pan American Continental Section which annually provides financial support amounting to some $20,000 for ICBP projects in Latin America.

From national sections:	
a) outside USA	12%
b) US section	3%
From ornithological organizations:	
a) outside USA	18%
b) within USA	15%
From World Wildlife Fund-US	26%
From World Wildlife Fund-International	26%
Total	£107,140

The US National Section of ICBP is composed of 19 member organizations, including all the major institutions of natural history and ornithology. In addition, a number of US foundations, trusts and institutions contribute towards projects in the ICBP Conservation Programme.

The major constraint on ICBP is poor access to funding sources for projects, especially in cooperation with governmental technical aid agencies, with the possible exception of Europe. This low profile is due to the relatively recent establishment of a professional Secretariat (the Director was appointed in 1980, and core staffing completed in 1984), and to the misconception that ICBP's remit is narrowly confined to the rather few threatened species of birds.

2.8. OTHER INTERNATIONAL AND INTERGOVERNMENTAL ORGANIZATIONS WITH INTERESTS IN MONITORING AND INVENTORY

This section only includes two organizations that have advanced plans for databases, or systems that are already operative. Other international organizations are certainly interested in this field. For example, ASEAN has a pilot project in Thailand.

2.8.1. COUNCIL OF EUROPE (COE)

Address: BP 431 R6, F-67006, Strasbourg Cedex, France

Ever since 1962, the year in which COE embarked on environmental activities, it has given high priority to inventory of environmental data, including fauna, flora and biotopes (Ribaut, 1984). COE has accumulated a considerable amount of data and is taking steps to computerize the information.

At present there are two databanks held on a Vax 750. The first of these covers all the birds listed on the "Convention on the Conservation of European Wildlife and Natural Habitats" (Bern Convention). About 500 species are included, many of them intercontinental migrants, with data on threats, protection status, taxonomy and habitats.

The second databank, collated since 1979 and operational since 1984, contains information on the European network of biogenetic reserves. Detailed descriptions of the reserves are held in free-text and in code, including information on position, size, ecology, fauna and flora etc. A programme for cooperation with the EEC has been instigated, and data will be exchanged with the EEC's CORINE database (see 2.8.2) (COE, 1985).

UNEP maintains regular contacts with COE, particularly the Council's Committee for the Conservation of Nature and Natural Resources (UNEP, 1984). IUCN, particularly CMC, and ICBP also have close links with COE, mainly concerning database design and species suitable for listing on the Bern Convention.

The 2nd colloquy on computer applications in the field of nature conservation was held in Strasbourg on 26-27 February 1985 under the auspices of COE's Environment and Natural Resources Division. Despite the great differences in the kinds of hardware and software used and the aims pursued, 50 participants representing databanks operated by 13 countries and international organizations decided to engage in active cooperation. Working parties were formed to consider a) the taxonomic problems involved in species classification systems, and b) biotope classifications and the use of databanks as a medium for action in the field of nature conservation. The report of the colloquy and a list of databanks can be obtained from the Environment and Natural Resources Division of COE (COE, 1985). The report is an excellent source of information on databanks in Europe.

2.8.2. COMMISSION OF THE EUROPEAN COMMUNITY (EEC)

In 1980 the Nature Conservancy Council of Great Britain was contracted to prepare a report on threatened species within the Community (Nature Conservancy Council, in press). Much of the work was sub-contracted to CMC, which also upgraded the report to include Greece in 1982. Although the report was intended for publication, it has not yet appeared in final form.

The European region's "Ecological Mapping" project resulted from the adoption in 1973 of the Action Programme of the European Communities on the Environment, which set out to improve the European environment (Council of Ministers, 1983). The general objective of the project was to provide a coordinated framework for the collection, storage and presentation of environmental data at a European level. The purpose of the framework was to provide a sound basis for Community environmental policy; help to strengthen the environmental component of policies in other sectors (e.g. agriculture, energy, transport); and provide a means of integrating national environmental data into a compatible regional database.

In 1976 a preliminary methodology for the project was prepared by a team in Munich, and a series of regional case studies were set up in member states in order to test it. A number of related studies were also initiated, examining aspects such as remote sensing, computer applications, natural hazards and compatibility with other information systems. As a result of all these studies an operational structure for a Coordinated Information System on the State of the Environment in Europe (now generally known by the acronym CORINE) has been developed. Five main areas of concern are included within the structure (Council of Ministers, 1983):

a) landscape and nature
b) land (mainly agricultural and forestry data)
c) water
d) air
e) natural hazards

Although the 1983 report recommended an immediate operational phase for CORINE, this was rejected by the Council of Ministers in favour of a phased operation beginning with a two-year phase (January 1985 - December 1987) to include four activities:

a) collection of digitized data from existing sources (e.g. topographical, meteorological, soils data);
b) compilation of a register of sites of special scientific interest, particularly from the point of view of nature conservation;
c) a pilot project to compile a wide range of environmental attributes in a defined area, the Mediterranean;
d) systems studies to assess hardware needs and software programmes.

Compilation of the environmental data during this two-year pilot phase falls to the project leader of d) above, Prof. David Rhind of Birkbeck College, University of London. Eventually the CORINE system will be operated from the Community's computing centre in Luxembourg. There are close links between the CORINE programme, UNEP/GEMS GRID systems, the Council of Europe databases, and the IUCN/CMC protected areas database.

3 CONSTRAINTS

3.1. Knowledge

To monitor and maintain global biological diversity requires baseline inventory data on the number of species of animals and plants and their distribution. Data are needed not for any idealistic plan to monitor each and every species; this would clearly be impossible. Rather the data are needed in order to give a scientific perspective to resource and biotope conservation, avoiding a narrow, and possibly misguided, perspective based on anthropocentric values.

Cataloguing animals and plants is primarily the work of systematists, the majority of whom work in museums of natural history. The extent to which the task has been completed since taxonomy began in the 17th century varies greatly between groups. In general the vertebrates are well known, particularly the homoiotherms. New birds and mammals are only rarely discovered, but up to a hundred new species of fish may be described each year, plus a few dozen amphibians and reptiles. Invertebrates are relatively poorly known, although the majority of species in the less diverse marine phyla are described. It is amongst the terrestrial invertebrates, notably the insects, that the biggest gaps in our knowledge are to be found. Great strides have been made since John Ray, at the close of the 17th century, estimated that there might be 20,000 species of insect in the world - we now know there is this number in the British Isles alone!

Table: Approximate numbers of described multicellular animals and plants (from various sources, including Parker, 1982; Huxley, 1985)

	Thousands of species	% of total
Insects	1000	57.9
Other arthropods	150	8.7
Other invertebrates	150	8.7
Fishes	26	1.5
Reptiles	5	0.3
Amphibians	3	0.2
Birds	9	0.5
Mammals	4	0.2
Subtotal (animals)	1347	
Non-flowering plants	130	7.5
Flowering plants	250	14.5
Subtotal (plants)	280	
Total	1727	100

Hundreds of new insect species are still being described every year, and there is some debate as to how many species exist. Traditional estimates of 1.5 to 4 million insects were recently brought into question when results from work in the tropical forest canopy showed that there may be several times this number (Erwin, 1982).

Some groups of plants are well known, particularly taxa of large physical dimensions or economic value. Nevertheless, much work remains to be done with the lower plants in particular, and in the tropical zones in general. Thousands, perhaps tens of thousands, of plant species still await discovery and description (see OTA paper in this series by P.H. Raven).

3.2. Technology

Although there are numerous national biological diversity databases from which experience on technological constraints may be gleaned, there is only one operating completely internationally, the IUCN database at CMC. Others are, of course, being developed (see section 4). CMC is actively building its database (manual and computer files) on global diversity and the factors threatening to reduce it. Thus, over the past five years, CMC has developed more experience than other institutions. As CMC grows to maturity, serious constraints on the computerization of data and the use of computer data can be highlighted. Here I am not concerned with technical aspects of computerization (storage space, software compatability etc.) for in these fields knowledge seems far ahead of application. More fundamental are the questions a) what data need to be computerized, and b) for what purpose?

In the same way that the limited number of taxonomists must carefully select the taxa they study, database builders must select what aspects of biological diversity are best suited to provide needed information (on centres of endemism and richness, for example) and which are best suited to monitoring (in terms of ease of recognition and ability to respond recognizably to environmental perturbations). As noted at the "Global Possible" conference, there is a need for agreement on key environmental indicators and standard geographical information systems to be used by international organizations and governments (WRI, 1984).

The technology of remote sensing is probably not at present a major constraint on the monitoring of biological diversity, since the procedures are well advanced. However, it is important that the GEMS system be improved and fully developed, with particular attention being paid to linking remote sensing data with field data from disparate sources.

3.3 Organization

Under this heading I include funding, staffing, political and institutional constraints on the gathering of data on biological diversity by international organizations. Constraints on the dissemination and usefulness of the data are considered in Section 5..

Funding and staffing are, predictably, major constraints on all the international efforts to inventory and monitor biological diversity. The international organizations most easily assisted by US funding include UNEP, IUCN and the UN specialised agencies. The

European initiatives (CORINE, Council of Europe) have less contact with the U.S. The main problems may be listed as follows:

a) UNEP/GEMS is understaffed;

b) GRID needs considerable financial support in its giant task;

c) CMC has outgrown its accomodation and computer hardware.

Political constraints of course have an impact on the functions of these organizations, but in general there is good East-West cooperation in environmental fields. Global environmental matters are perceived by all heads of state as a common heritage of international concern, as evidenced for example by the Nixon-Brezhnev accord (section 2.3.3.). Even in UNESCO, where political disagreements caused the recent resignation of the US, arguments centre around the educational, cultural and underlying political activities of the organization, not on its scientific initiatives, which have received considerable acclaim (e.g. MAB programme).

At the level of biological diversity, data on faunas, floras and threatened species are widely available without political restriction. National Red Data Books, containing data on threatened species, are being published regularly (e.g. Bannikov and Sokolov, 1984; see Burton, 1984 for bibliography). CMC has good contacts in most countries in the world, through the network of commissions and international membership of IUCN. Similarly, UNESCO's MAB programme has a fine network of national committees.

Exchangability of currency is a constraint on all organizations funded internationally. These include UNEP, FAO, UNESCO and IUCN.

At the institutional level no serious omissions were noted by the "Global Possible" conference (WRI, 1984), a perception that is supported here. IUCN has been developing expertise for nearly 40 years and since the UN Conference on the Human Environment held in Stockholm, 1972, many of the other institutions needed for effective international action have been built up. UNEP, IUCN and the UN specialised agencies function in a well-coordinated way, through regular meetings of the Ecosystems Conservation Group (section 2).

One possible area for improvement lies in the coordination of major national museums and records centres in their efforts to inventory the world's wildlife. New distributional faunistic and floristic data are constantly accumulating. Many of these new records are (or should be) recorded by national records centres and mapping schemes. On a national scale the Australian Biological Resources Study is a model for others (Busby, 1979; ABRS, 1983). ABRS is a co-ordinated national programme to describe and classify all Australian flora and fauna and to record their natural distributions. Other notable efforts include those of the Biological Records Centre at Monks Wood, U.K., the mapping programme at Gembloux, Belgium, and several other European initiatives. There is much room for improvement in linking such national efforts into an international framework for access to the global databases (GEMS, CMC). UNESCO, through IUBS, has made some initiatives (such as setting up the European Invertebrate Survey), but little cooperation has been achieved so far. Without a proper secretariat and adequate funding progress is inevitably very slow.

4 DATA STORAGE

Methods used to store data have been described in detail in section 2, as have the names and locations of the organizations involved. The main international computer data storage centres of the future will be the IUCN/CMC (linked with ICBP), GRID and CORINE systems. CORINE is still in a pilot phase, with hardware and software requirements being estimated at Birkbeck College, London. GRID is also in a pilot phase in Geneva and Nairobi, but proceeding rapidly. Once operational, it is envisaged that most data on biological diversity being fed to GRID will be available electronically from IUCN/CMC and ICBP at least at the species level. Data on protected areas will also come from CMC, but ecosystem, biome and global data will come from a variety of sources, national and international.

Retrievability and cross-compatability of computerized data pose some serious problems for the future, not in terms of hardware and technology, but in terms of software and organization.

The technology to transfer data from one system to another seems to be generally available. Indeed a whole industry has built up around this subject because it has been to the advantage of smaller systems and peripherals to communicate directly with the big names of the computer world. Standards for international and national transfer of data have been proposed, but transferring data is not quite the same as integrating it. To integrate data, it must be in a standard, easily read and understood format. Compatability of data being entered into GRID is discussed in 2.1.6., and for CORINE in 2.8.2. These international efforts to integrate data require enormous effort to produce comprehensive software. Once it is devised there may be problems in its acceptability. Who will carry out these movements of data, and, perhaps more importantly, who will pay for it?

There is one important caveat to the extensive use of international databases; this concerns the level of availability. All databases comprise a matrix of new and old information, some reliable, some less so. Administrators of databases should not give free access of scientific data to decision-makers, politicians and others who are not trained in its interpretation. Analysis of environmental data, whether it be on biological diversity or any other form of base-line information, must fall to people who understand:

a) the context within which the data were entered onto the database;

b) the state of completeness and reliability of the data, and

c) the way in which the data were sampled and gathered (e.g. aerial data are not as accurate as data from a ground-truth survey).

It is also important to realise that the process of transferring data from a word format to a data format on a computer must itself require some sifting procedures that may serve to obscure the very facts which decision-makers require.

5. USEFULNESS OF DATA

Environmental decision-makers sometimes experience difficulty in obtaining the information they require. As a result, there is a perception that international organizations are not gathering suitable types of data. This is a misconception caused by the lack of mechanisms to transfer data from the organizations to the decision-makers. By creating the proper mechanisms, a wealth of useful environmental data will become available.

Data on natural resources, impacts on climate, movements of pollutants and the state of oceans are available through UNEP/GEMS and the UN operative agencies. Data on threatened ecosystems, endangered animals and plants, wildlife trade and protected areas are available from IUCN/CMC, and the information is constantly being reviewed and up-dated within the organization's financial constraints. All international organizations try to transfer their data effectively (in publications, educational material, offers of assistance etc.), but without an inquisitive and receptive audience, the task is difficult. The World Conservation Strategy (IUCN et al., 1980) has done much to bridge the information gap. Now that governments are accepting their environmental responsibilities more willingly, new mechanisms for data transfer can be designed. Governments may be assured that much of the data they need is available - all they have to do is ask for it and help in its transfer. It is essential that enquiries are formulated at an early stage in planning and not, more cynically, when the plans are already well advanced.

Once the mechanisms for information transfer are created, effective conservation of biological diversity can quickly be achieved. For example, in the UK there is an umbrella conservation organization, Wildlife Link, that has good channels of communication with government. Wildlife Link knows of CMC's capacity and can call upon IUCN's resources whenever it needs to do so. In 1984 Henderson Island in the Pitcairn Group was saved from damaging human colonization by a report requested by WWF, IUCN and ICBP, prepared largely by CMC staff, and very quickly submitted to the UK Foreign and Commonwealth Office through Wildlife Link. Umbrella organizations in the US (e.g. Monitor) and elsewhere could develop similar lines of communication.

The impact of Red Data Books is difficult to assess, but, for example, a number of cases of effective conservation have resulted from the publication of the IUCN Invertebrate Red Data Book (Wells, Pyle and Collins, 1983). To name a few: the Giant Gippsland earthworm has been added to the Victoria State protected list; a number of endemic snails are being aided by efforts to protect the Cuatro Cienegas wetland in Mexico; the Hemiphlebia damselfly has been rediscovered in Australia; various European Large Blue butterflies (Maculinea spp.) have been closely studied and are now candidates for protection under the Bern Convention; Stony Corals and the Red-Kneed Tarantula have been added to Appendix II of the Washington Convention. Similar case-histories could be related for other RDBs.

On another front, the IUCN Conservation for Development Centre (CDC) is actively promoting the preparation of National Conservation Strategies, in line with the philosophy of the World Conservation Strategy (IUCN et al., 1980). Ideally, national centres will be developed to implement these strategies, and there are long-term plans to give the centres access to the CMC database, as a basis for monitoring activities.

In many cases it is very difficult accurately to assess to what extent documents prepared by international organizations are being used in planning. The FAO tropical forest assessment (FAO, 1981 a;b;c) is without doubt an invaluable document to many forestry departments around the world, but the full impact of the work may never be known. A number of applications of UNEP's monitoring activities have been noted in Section 2.1.3.

Nevertheless, such examples of the successful utilisation of data represent only a fraction of what could be achieved. Much more could be done by international organizations to effect conservation measures, but policy-making mechanisms hamper expeditious reponses to new situations. In IUCN, for example, policy guidance is given by the Commissions, a role central to their existence. Yet the Commissions do not have mechanisms to respond in a fast and unified way. Creating the mechanisms to overcome such barriers is the key to progress. Money, willingness and dialogue can make it happen.

6. SUGGESTED ACTIONS

The following objectives and actions are not presented in any order of priority.

Objective 6.1. Improve linkages between centres of biological records, taxonomy, systematics or biogeography and organizations involved in inventory and monitoring at the international level.

Action 6.1.1. Help herbaria, museums and records centres to develop computer storage of biological data for ease of transfer to environmental databases.

Action 6.1.2. Encourage museums to rate conservation and environmental studies as priority applications of biological data (equivalent to pest studies etc.) Encourage links between museums and international bodies such as IUCN, WWF, UNEP, so that species and community data can be used for analytical purposes.

Action 6.1.3. Encourage the study and identification of indicator taxa for use in biogeographical analyses for planning of conservation strategies. Such taxa should be chosen for their responses to environmental change, their diversity, and the degree to which they are known. Poorly known groups which fill other criteria as indicators should be singled out for future research.

Objective 6.2. Continue to support and expand US-based research programmes that have direct application to international efforts to inventory and monitor biological diversity. Encourage free exchange and application of new technologies whenever and wherever possible.

Action 6.2.1. Catalogue those US organizations that are involved in relevant technologies. Assess ways in which they may be supported.

Action 6.2.2. In cooperation with international bodies, help US organizations to carry out research on important environmental and resource indicators for worldwide monitoring.

Action 6.2.3. Stimulate the further development and application of remote-sensing technologies.

Action 6.2.4. Stimulate input of information on biological diversity from US centres of taxonomic research to international organizations (see 6.1.).

Action 6.2.5. Encourage standardization and quality control of data through provision of sectoral experts to participate in data validation, coding, input and analysis at major international databases such as GRID and that of CMC.

Objective 6.3. Encourage awareness and support of the efforts of those international organizations that have programmes for inventory and maintenance of biological diversity.

Action 6.3.1. Continue financially to support UNEP and give encouragement to the Earthwatch programme.

Action 6.3.2. Assist the UNEP/GEMS Programme Advisory Centre by seconding suitable technical US staff to GEMS.

Action 6.3.3. Support the UNESCO Man and Biosphere programme by contractual arrangements with national or other MAB sections. Encourage the implementation of the "Action Plan for Biosphere Reserves" at home and abroad (UNESCO, 1984).

Action 6.3.4. Support the IUBS initiative "Decade of the Tropics" and particularly its efforts to study the significance of species diversity in tropical forest ecosystems. The programme is closely allied to the MAB programme of UNESCO.

Action 6.3.5 In acknowledgement of the importance of the "World Conservation Strategy" (IUCN, UNEP, WWF, 1980), support the IUCN Conservation Programme 1985-1987 "Implementing the World Conservation Strategy", which includes establishment of a task force on biological diversity, a number of studies on the effectiveness of protected areas systems in maintaining biological diversity, and entire Programme Areas devoted to "Conservation Monitoring and Data Analysis" and "Promoting conservation of Species and Their Populations" (IUCN, 1985).

Action 6.3.6. Work closely with policy research centres (WRI, IIED) that focus on global-scale resource and environmental issues to bridge the gap between basic research and policy.

Objective 6.4. Utilize existing and proposed databases to the full. In this way they will grow and adapt quickly to user needs.

Action 6.4.1. Advise all US agencies to be aware of the impacts on biological diversity that US policies and actions may have. Encourage all agencies to carry out thorough searches in environmental databases whenever such impacts seem possible or likely.

Action 6.4.2. Give all possible technical, material and financial assistance to the development of the GEMS GRID system. In particular, take steps to achieve greater worldwide consensus on monitoring, units of measurement and geographical formats.

Action 6.4.3 Direct environmental impact enquiries to IUCN, CDC and CMC as part of any development package in foreign countries. Advise that other national and international development agencies do likewise.

Action 6.4.4. Direct enquiries concerning the status of plant and animal species, the status of protected areas, and the impact of wildlife trade on species to CMC. Explore all avenues for greater cooperation between CMC and US agencies and organizations.

Action 6.4.5. Commission from ICBP analytical documents on sites and bird species of major international importance (economically, biologically, ecologically).

Action 6.4.6. Support the CORINE programme of the EEC by free transfer of digitized topographical and other data from whatever sources are available.

These objectives have particular relevance to the subject of the present paper, i.e. inventory and monitoring. If they are to be successful in helping to maintain biological diversity, they must be achieved in concert with four other important objectives:

a) encourage enforcement of international treaties and conventions protecting wildlife (see OTA paper in this series by John Barton);

b) encourage the completion and better management of a network of protected areas (see OTA papers by J. Harrison and J. Thorsell);

c) address the universal shortage of personnel in resource management, forestry, genetics, taxonomy and ecology by increasing funds for training, especially in less developed countries;

d) develop an international programme to improve public understanding of the importance of biological diversity, and of the impacts that reductions in biological diversity may have on human welfare.

REFERENCES

ABRS, "Annual Report 1981-82", Canberra Australian Govenment Publishing Service, 15pp, 1983.

Angel, M.V. "Ocean Trench Conservation", Commission on Ecology Occasional Paper Number 3, 1981.

Anonymous, "Biotopes of significance for nature conservation", a European Case Study undertaken in the framework of the project "Ecological Mapping" of the European Community for the creation of an information system on the European Community, 50 pp., + annexes. Ref. XI/94/83, 1982.

Anonymous, "Action plan for Biosphere Reserves" Nature and Natural Resources 20(4): 11-22, 1984.

Bie, S.W. (Compiler) "Report on ad hoc Expert Group meeting to review hardward and software criteria for a Global Resource Information Database". Nairobi, GEMS, unpublished report, 45 pp., 1983.

Bannikov, A.G. and Sokolov, V.I. (eds), "The Red Data Book of the USSR Rare and Threatened Species of Animals and Plants", Moscow, Lesnaya Promiishlyennost Press (in Russian), 1984.

Burton, J.A. "Bibliography of Red Data Books. Part 1, animal species", Oryx 18 (1): 61-64, 1984

Busby, J.R. "Australian Biotaxonomic Information System. Introduction and Data Interchange Standards", Canberra, Australian Government Publishing Service, 25pp.

COE, "Catalogue of Data Banks in the Field of Nature Conservation", Strasbourg, Council of Europe, 109pp, 1985.

Collar, N.J. and Stuart, S.N. "Threatened Birds of Africa and Related Islands. The ICBP/IUCN Red Data Book Part 1", Cambridge, IUCN, xxxiv + 761 pp., 1985.

Collins, N.M. and Morris, M.G. "Threatened Swallowtail Butterflies of the World, The IUCN Red Data Book", Cambridge, IUCN, vii + 401 pp. + 8 col. pls., 1985.

Commission on Ecology, "Global Status of Mangrove Ecosystems", Commission on Ecology Papers Number 3, 88 pp., 1983

Council of Ministers, "A Methodological Approach to an Information System on the State of the European Environment", Strasbourg, Council of Europe, COM(83)528, 1983.

Croze, H., "Global monitoring and biosphere reserves", Conservation, Science and Society, Proceedings 1st International Biosphere Reserve Congress, Minsk, Byelorussia, USSR, 26 September-2 October 1983, pp 361-370. UNESCO-UNEP, 1984.

Di Castri, F., Hadley, M., Damlamian, J., "MAB: the Man and the Biosphere Program as an evolving system", Ambio 10 (2-3): 52-57, 1981.

Erwin, T.L., "Tropical forests: their richness in Coleoptera and other arthropod species", Coleopterists' Bulletin 36(1): 74-75, 1982.

FAO, "Global Environment Monitoring System:, Pilot Project on Tropical Forest Cover Monitoring, Benin - Cameroon - Togo", (Project Implementation: Methodology, Results, and Conclusions.) Project Report No. 4, ix + 99 pp., Rome, FAO, 1980.

FAO, "Animal genetic resources conservation and management", Proceedings of the FAO/UNEP Technical Consultation. FAO Animal Production and Health Paper No. 24, 1981.

FAO, "Proyecto de Evaluacion de los Recursos Forestales Tropicales (en el Marco del Sistema Mundial de Vigilancia sel Medio Ambient - SIMUVIMA). Los Recursos Forestales de la America Tropicale", Food and Agriculture Organization of the United Nations (FAO), Rome, Italy: Informe Tecnico 1, vi + 343 pp, 1981a.

FAO, "Tropical Forest Resources Assessment Project (in the Framework of GEMS). Forest Resources of Tropical Africa", Food and Agriculture Organization of the United Nations (FAO), Rome, Italy: 2 vols, vii + 106 pp. and iv + 586 pp, 1981b.

FAO, "Tropical Forest Resources Assessment Project (in the Framework of GEMS). Forest Resources of Tropical Asia", Food and Agriculture Organization of the United Nations (FAO), Rome, Italy: Technical Report 3, ix + 475 pp, 1981c.

FAO, "Animal genetic resources conservation by management, data banks and training", Proceedings of the Joint FAO/UNEP Expert Panel Meeting, October 1983, Part 1, FAO Animal Production and Health Paper 44/1, 1984.

GEMS, "The Global Assessment of Tropical Forest Resources", GEMS PAC International Series, No. 3, 14 pp., 1982.

Griffiths, [illegible]., "Address of welcome", Animal Genetic Resources Conservation by Management, Data Banks and Training, in FAO, 1984, pp. 3-4.

Groombridge, B. and Wright, L., "The IUCN Amphibia-Reptilia Red Data Book, Part 1", Cambridge, IUCN, xliii + 426 pp., 1982.

Gwynne, M.D. & Croze, H., "East African habitat monitoring practice: A review of methods and application", Pp. 95-135 in Evaluation and Mapping of Tropical African Rangelands: Proceedings of a Seminar Held in Bamako, Mali, 3-8 March 1975, Addis Ababa, ILCA, 1978.

Hodges, J., "Review of the FAO/UNEP programme on animal genetic resources conservation and management", in FAO, 1984, pp. 5-10.

Hodges, J., "The current projects for creation of data banks by FAO/UNEP", in FAO, 1984, pp. 117-119.

Hodges, J., "Recommendations of the FAO/UNEP expert consultation on methodology for animal genetic resources data banks." Rome, FAO (in press).Huxley, A., "The Green Inheritance", London, Collins, 193 pp., 1984.

IBPGR, "Annual Report 1983", Rome, IBPGR, FAO, 126pp., 1984.

ICBP, Annual report 1983. XVI Bulletin, 64 pp., 1984.

IUCN, "IUCN Directory of Neotropical Protected Areas", Dublin, Tycooly International, 436 pp., 1982.

IUCN, "Implementing the World Conservation Strategy, IUCN's Conservation Programme 1985-1987," Gland, IUCN, 1985.

IUCN/CMC, "A preliminary environmental profile of the India-Pakistan borderlands in the Sind-Kutch region, a report for the World Bank", Cambridge, IUCN, 60pp, 1983.

IUCN/CMC, "A preliminary report on threatened and endemic vertebrate species in Ethiopia", Cambridge, IUCN, 1984.

IUCN/CMC "A preliminary report on threatened species and areas in Madhya Pradesh (India)", Cambridge, IUCN, 1984.

IUCN, UNEP and WWF, "World Conservation Strategy: Living Resource Conservation for Sustainable Development", Gland, IUCN, 1980.

Lucas, G. and Synge, H., "The IUCN Plant Red Data Book", Gland, IUCN, 540 pp., 1978.

Maury-Lechon, G., Hadley, M., and Younès, T., "The significance of species diversity in tropical forest ecosystems", Biology International Special Issue 6, 76 pp, 1984.

Morton, A., "Earth seen from above", Naturopa 48: 22, 1984.

M'Bow, A.-M., "Man and the Biosphere. The first ten years of UNESCO's environmental programme", Unesco Courier April 1981: 4-5.

Nature Conservancy Council of Great Britain, "Community List of Threatened Species of Wild Flora and Vertebrate Fauna", Commission of the European Communities. (Draft prepared 1980, updated to include Greece 1982, currently in press).

Parker, S.P., "Synopsis and Classification of Living Organisms", New York, McGraw-Hill, 2 vols., 1232 pp., 1982.

Phillips, B., "The ICBP oceanic islands data base: a preliminary demonstration", ICBP Study Report No. 5, 45 pp., 1985.

Sokolov, V., "The Biosphere Reserve concept in the USSR", Ambio 10(2-3): 97-101.

Solbrig, O.T. and Golley, F.B., "A Decade of the Tropics" Biology International Special Issue 2, 15pp., 1983.

Thornback, J. and Jenkins, M. "The IUCN Mammal Red Data Book. Part 1", Gland, IUCN, xl + 516 pp., 1982.

Turton, J.D., "The Commonwealth Bureau of Animal Breeding and Genetics and the provision of information for data banks on animal genetic resources", in FAO, 1984, pp. 142-147.

UNEP, "Annual Report of the Executive Director 1983", Nairobi, UNEP, 192 pp., 1984.UNEP, "Annual Report of the Executive Director 1984" Nairobi, UNEP, 176 pp., 1985.

UNEP/GEMS, "Global Resources Information Database", Nairobi, UNEP/GEMS, 16pp., 1985

UNESCO, "Action Plan for Biosphere Reserves "Nature and Resources 20(4): 11-22, 1984.

Wells, S.M., Pyle, R.M. and Collins, N.M., "The IUCN Invertebrate Red Data Book", 1 + 632 pp., Cambridge, IUCN, 1983.

Whittaker, R.H., "Evolution of species diversity in land communities", Evolutionary Biology 10: 2-67, 1977.

Wiggins, J., Green, N. and Rhind, D. "Data transfer within the CORINE project", CORINE Working Paper No. 1, June 1985.

WRI, "The Global Possible", Washington D.C., World Resources Institute, 38 pp., 1984.

WWF-US, "Conservation Program 1986-1990" Washington D.C., WWF-US, 1985.

ABBREVIATIONS

ABRS	Australian Biological Resources Study
ALPA	Latin American Association of Animal Production
ASEAN	Association of South-East Asian Nations
CAB	Commonwealth Agricultural Bureaux, Commonwealth Bureau of Animal Breeding and Genetics
CDC	IUCN Conservation for Development Centre
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMC	IUCN Conservation Monitoring Centre
CNPPA	Commission on Natural Parks and Protected Areas
CoE	Commission on Ecology
COE	Council of Europe
EEC	European Economic Community
EMU	Ecological Monitoring Unit
FAO	UN Food and Agriculture Organisation
GEMS	Global Environment Monitoring System
GRID	Global Resource Information Database
IBAR of OAU	Inter-African Bureau for Animal Resources of the Organisation of African Unity
IBPGR	International Board for Plant Genetic Resources
ICBP	International Council for Bird Preservation
IDRC	International Development Research Centre
IIED	International Institute for Environment and Development
ILCA	International Livestock Centre for Africa
ILO	International Labour Organization
IUBS	International Union of Biological Sciences
IUCN	International Union for Conservation of Nature and Natural Resources
KREMU	Kenya Rangeland Ecological Monitoring Unit
MARC	Monitoring and Assessment Research Centre
NAS	National Academy of Sciences, USA
NCC	Nature Conservancy Council, UK
NOAA	National Oceanic and Atmospheric Administration, USA
OECD	Organization for Economic Co-operation & Development
PAC	Programme Advisory Centre of GEMS
RSPB	Royal Society for the Protection of Birds, UK
SABRAO	Society for the Advancement of Breeding Research in Asia and Oceania, Kuala Lumpur
UN	United Nations
UNEP	United Nations Environment Programme
UNESCO	UN Educational, Scientific & Cultural Organization
WHO	World Health Organization, Geneva
WMO	World Meteorological Organization
WRI	World Resources Institute, Washington D.C.
WWF	World Wildlife Fund

Contract Paper No. 3

The Role of Protected Areas in Maintaining Biological Diversity in Tropical Developing Countries

James W. Thorsell
International Union for the Conservation of Nature and Natural Resources

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The Role of Protected Areas in Maintaining Biological Diversity with Special Reference to Tropical Developing Countries

> "No effort is likely to contribute as much to the conservation of living diversity as the creation of parks and other protected areas where complete living communities can continue to evolve".
>
> E.C. Wolf in State of the World 1985, p. 145.

1. INTRODUCTION

In recent years managers of protected areas around the world have been asked to add a new perspective to their activities. In addition to their traditional concern to protect and manage for species diversity within protected areas, they are also being asked to conserve genetic variability within species. Much of the scientific background upon which this management of biological diversity is based (e.g. minimum viable population size, endemism, rarity, community stability, extinction rates) has been developed from the recently-evolved field of conservation biology which applies scientific principles from genetics, ecology, and biogeography to conservation.

The purpose of this paper is to review activities underway that contribute to strengthening efforts to conserve biological diversity with special emphasis on protected areas in tropical developing countries and to suggest how these can be extended.

The paper is largely based on guidelines, principles and action strategies prepared by IUCN's Commission on National Parks and Protected Areas (CNPPA) and on work currently in progress in the tropical realms. Since 1960 the Commission has played a leading role in protected area conservation, particularly in the tropics. It has a current membership of 300 park professionals in 119 countries and works in partnership with Unesco, UNEP, FAO and WWF, as well as the total IUCN network in carrying out its programme. The perspective is thus an international one with a strong orientation to where the world's biological diversity is mostly concentrated -- the tropics.

2. CURRENT STATUS OF PROTECTED AREAS IN TROPICAL DEVELOPING COUNTRIES

Table 1 provides a summary of the current "estate" or inventory of protected areas in the tropics, including four of the eight biogeographic realms of the world (Fig. 1). There are some additional areas that could also be considered tropical in the Australian Realm (e.g. North Queensland) and in the Palaearctic Realm (e.g. portions of the Himalaya-Hindukush) but, for simplicity, only realm boundaries are included in this table. (Presentation of the total world coverage of protected areas is contained in the companion paper prepared by Jeremy Harrison of IUCN's Conservation Monitoring Centre).

TABLE 1: WORLD COVERAGE OF PROTECTED AREAS IN THE TROPICS
(Categories I-V)

Biogeographic Realm	No. of Protected Areas	Area (ha)
Afrotropical	426	88,166,096
Australian	75	10,752,012
Inodmalayan	572	27,568,406
Neotropical	296	43,503,474
Oceanian	51	4,108,584
Total:	1420	174,098,572

Based on IUCN (1985)

Another way of reviewing existing coverage is to compile the number and size of protected areas that occur within the 12 different biomes in the tropical realm. This is presented in Table 2, and, although the figures are less precise than Table 1, the general pattern can be seen. (For further explanation on the use and interpretation of these tables, see Harrison, et al., 1982; Harrison, OTA Report, 1985).

These quick summaries of protected areas by realm and by biome reflect the importance of the work done by IUCN's Conservation Monitoring Centre in compiling a data base on protected areas on a global basis. This centre works with CNPPA in compiling the periodic United Nations List of National Parks and Protected Areas (the 1985 List is in press) and in preparing more detailed directories of protected areas on the different realms. One such directory has been published for the Neotropical Realm (IUCN, 1982), the Afrotropical volume is in press, and a third, for the Indomalayan Realm is in preparation. The collection and presentation of protected area information is an important tool used by governments, development agencies, and individuals and provides a fundamental data base for understanding where biological diversity is currently protected.

TABLE 2: PROTECTED AREA COVERAGE OF BIOMES IN TROPICAL REALMS

BIOME	NUMBER OF AREAS	TOTAL AREA (HA)
Tropical humid forests		
Afrotropical	44	8,905,733
Indomalayan	122	5,092,774
Australian	53	7,776,347
Neotropical	61	17,277,197
	280	39,052,051
Tropical dry forests/woodlands		
Afrotropical	240	48,673,552
Indomalayan	238	10,420,406
Australian	10	934,272
Neotropical	93	5,501,447
	581	65,529,677
Evergreen sclerophyllous forests		
Afrotropical	41	1,620,967
Neotropical	5	38,795
	46	1,659,762
Warm deserts/semi-deserts		
Afrotropical	57	23,783,085
Indomalayan	35	1,628,854
Neotropical	7	1,446,751
	99	26,858,690
Tropical grasslands/savannas		
Australian	12	2,041,393
Neotropical	18	7,011,403
	30	9,052,796
Mixed mountain systems		
Afrotropical	38	5,104,626
Neotropical	86	11,037,282
	124	16,141,908
Mixed island systems		
Afrotropical	4	23,033
Indomalayan	177	10,426,372
Oceanian	51	4,108,584
Neotropical	26	1,190,599
	258	15,748,588
Lake systems		
Afrotropical	2	55,100
	2	55,100
	1420	174,098,572

Based on IUCN (1985), IUCN Management Categories I-V

3. THE ADEQUACY OF THE CURRENT SYSTEM OF PROTECTED AREAS IN THE TROPICAL REALMS

174 million ha of land and water under protection is a sizeable area of land, almost equivalent in size to Mexico and about one fifth as much as land under cereal crop production worldwide. But is this area really adequate to conserve the species and ecosystems functions required for preservation of biological diversity? Setting aside for the moment the question of how effectively the existing areas are managed, the answer is a clear "no". Two main lines of evidence point to this inadequacy.

3.1. Biogeography and protected area design

Advances in the theory of island biogeography (MacArthur and Wilson, 1967, Wilcox, 1980) suggest that any time the total area of an ecosystem is reduced, species diversity will decline until it reaches a new equilibrium for the size of the ecosystem. It is clear that no reduced area, no matter how well protected, can ultimately retain all its original species when it becomes an "island" of original natural habitat surrounded by other forms of land use. The larger the reserve, the less severe and slower the species loss, but the clear conclusion is that any loss of natural habitat will very likely lead to a loss in species. A suggested rough estimate is that a single reserve containing 10 percent of the original area may eventually support only 50 percent of the original species present.

3.2. Population genetics

The science of population genetics has led to a rethinking of what a protected area must do to ensure long-term survival of species. Questions of short-term fitness, long-term adaptation, relations between genetic heterozygosity and reproductive behaviour, and the continued opportunity for evolution of species have been analyzed. It has become clear that large population sizes are required by species which are least dense, such as the large herbivores, carnivores, scavangers, and trees. Avoiding inbreeding depressions requires populations to be maintained at levels greater than 50 reproducing individuals or even 500 or 5000 (Frankel and Soulé, 1980) but further studies are needed on this issue.

Determining the theoretical minimum size of a protected area required to conserve genetically viable populations of all species is a fairly simple mathematical operation, once all the uncontrollable variables are declared controlled. Simply take the least dense species (many trees occur in tropical forest at densities of 1 per ten hectares, and adult male orangutans may have a density of one per 100 hectares in the richest habitats), determine the minimum genetically-viable population size, and multiply the density by the population to give the total area required. For wide-ranging species such as tigers or elephants, it may no longer be possible to have reserves of sufficient size to ensure their long-term survival, unless active genetic management measures are instituted.

In conclusion, it is obvious that we cannot be totally dependent on protected areas for preservation of biological diversity. The relatively small amount (less than 2 percent) of the tropics that is currently protected would have to be increased perhaps 5-fold to be considered adequate, and even then we must still expect some species extinctions within each area. Although IUCN's Bali Action Plan (see section 8.2) suggests a target of 10% for a country, conservation systems should be biased in favour of areas of high species richness. Thus, Myers (1979) has recommended that for tropical forests the targets should be 20%, for temperate forests they should be 10%, and for boreal areas, 5%. Although some increases are forecast, land use options are quickly being closed. Other measures are needed, augmented by more effective management of existing sites.

3.3. Current coverage assessment project

To assess the adequacy of protected area coverage in three of the tropical realms (Afrotropical, Indomalayan, and Oceanian) IUCN is currently conducting a systems review (i.e. coverage evaluation) of all protected areas. The methodology of this approach incorporates recent advances in the science of conservation biology (MacKinnon, 1985) and will provide, for the first time, a scientific assessment of how well biological diversity is contained within existing protected areas in these three realms. These reviews have the objectives of:

- identifying gaps and shortcomings;
- recommending where additional protected areas are needed;
- identifying priorities for strengthening protection;
- considering the suitability of the status, boundaries, design and effectiveness of the existing reserve system; and
- identifying conservation management needs in critical habitats outside protected areas.

As a basis for conducting the reviews, the Conservation Monitoring Centre (CMC) of IUCN have been commissioned to prepare an up-to-date directory of protected areas in the respective countries, listing and plotting the location of each reserve and giving the main details of the area's status, condition, contents and management. The current reviews are evaluating these data from a number of different viewpoints:

- coverage by proportional area of each biogeographical sub-division;
- coverage of the regional and altitudinal range of each sub-division and inclusion of other features (eg. physical or ethnic interests) that need protection;
- coverage in relation to species richness, centres of high biological distinctiveness or endemism and in relation to relative habitat threat;
- coverage in relation to commercial interest or value of content (e.g. genepools etc.);
- review category status of the various protected areas and whether this needs revision;
- evaluation of protected area system design on the basis of island biogeographical theory;
- management effectiveness; and
- consideration of adjacent land-use and critical habitat requirements.

Conservation biology and biogeographic theory are thus being applied in three major realms with results to be available in 1986. (A proposal for a similar review of protected area coverage in the Neotropical Realm has been submitted to USAID).

4. JUSTIFYING PROTECTED AREAS IN TROPICAL REALMS

As demands for efficient and immediate utilization for natural resources increase worldwide, particularly in under-developed countries with fast-growing populations, justification for the existence of protected areas must be clarified. To survive these pressures protected areas must be justifiable in both biological and socio-economic terms. Since government officials and the public generally undervalue the role of protected areas in environmentally-sound development, protected areas be designed and managed in ways that bring real benefits to local and national human communities. Conservationists must arm themselves with all the facts to defend the area's protected status in the first place; they must be able to counter in a convincing, cogent and eloquent manner such threatening questions as:

"Why do you need a reserve here?"

"Why must it be so large?"

"Couldn't you manage just as well with half the area?"

"Why can't we collect wood in the reserve?"

"Why should I tolerate my cows being eaten and my wife being terrified by your tigers?"

"Why bother to save tigers at all?"

"What's in it for us?"

"We need this land for agriculture to survive; why is it more important to save elephants than to let us live?"

It is obvious that protected areas need to be linked with human needs and with ecologically-sound development which can take on a more evident and practical meaning for governments and local people. Biological diversity by itself is not a sufficient single rationale but part of a set of 12 objectives suggested by Miller (1980) that together provide these linkages (Table 3).

5. CATEGORIES OF PROTECTED AREAS AND THEIR REGIONAL INTEGRATION

To accommodate this wider range of management objectives without giving up any of the important gains made by national parks and other strictly-protected categories, IUCN (1984a) devised a system of categories of conservation units (Table 4). These categories show, for example, that while nature reserves (category I) and national parks (II) must be strictly protected against resource extraction, their objectives can be reinforced by adjacent protected landscapes (V), resource reserves (VI), natural biotic areas (VII) and multiple-use management areas (VIII) where some carefully-controlled resource exploitation is permitted. Care in applying the categories framework is essential, however, as opportunistic interpretations of the extent of utilization within some categories have been made (Rijkson, 1984).

A series of case studies illustrating how a range of complementary protected area categories have been applied by governments to meet their responsibilities for protecting biological diversity while providing for human development on a sustainable basis is presented in McNeely and Miller (1984).

TABLE 3: CONSERVATION OBJECTIVES FOR PROTECTED AREAS IN THE TROPICS

1. Maintain ecological processes. To maintain large areas as representative samples of each major biological region of the nation in its natural unaltered state for ensuring the continuity of evolutionary and ecological processes, including animal migration and gene flow.

2. Biological diversity. To maintain examples of the different characteristics of each type of natural community, landscape and land form for protecting the representative as well as the unique diversity of the nation, particularly for ensuring the role of natural diversity in the regulation of the environment.

3. Genetic resources. To maintain all genetic materials as elements of natural communities, and avoid the loss of plant and animal species.

4. Education and research. To provide facilities and opportunities in natural areas for purposes of formal and informal education and research, and the study and monitoring of the environment.

5. Water and soil conservation. To maintain and manage watersheds to ensure an adequate quality and flow of fresh water, and to control and avoid erosion and sedimentation, especially where these processes are directly related to downstream investments which depend upon water for transportaiton, irrigation, agriculture, fisheries, and recreation, and for the protection of natural areas.

6. Wildlife management. To maintain and manage fishery and wildlife resources for their vital role in environmental regulation, for the production of protein, and as the base for industrial, sport, and recreational resources.

7. Recreation and tourism. To provide opportunities for healthy and constructive outdoor recreation for local residents and foreign visitors, and to serve as poles for tourism development based upon the outstanding natural and cultural characteristics of the nation.

8. Timber. To manage and improve timber resources for their role in environmental regulation and to provide a sustainable production of wood products for the construction of housing and other uses of high national priority.

9. Cultural heritage. To protect and make available all cultural, historic and archeological objects, structures and sites for public visitation and research purposes as elements of the cultural heritage of the nation.

10. Scenic beauty. To protect and manage scenic resources which ensure the quality of the environment near towns and cities, highways and rivers, and surrounding recreation and tourism areas.

11. Options for the future. To maintain and manage large areas of land under flexible land-use methods which conserve natural processes and ensure open options for future changes in land use, incorporate new technologices, meet new human requirements, and initiate new conservation practices as research makes them available.

12. Integrated development. To focus and organize conservation activities to support the integrated development of rural lands, giving particular attention to the conservation and utilization of marginal areas and to the provision of stable rural employment opportunities.

TABLE 4: CATEGORIES AND MANAGEMENT OBJECTIVES OF PROTECTED AREAS

I. Scientific Reserve/ Strict Nature Reserve. To protect nature and maintain natural processes in an undisturbed state in order to have ecologically representative examples of the natural environment available for scientific study, environmental monitoring, education, and for the maintenance of genetic resources in a dynamic and evolutionary state.

II. National Park. To protect natural and scenic areas of national or international significance for scientific, educational, and recreational use.

III. Natural Monument/Natural Landmark. To protect and preserve nationally significant natural features because of their special interest or unique characteristics.

IV. Managed Nature Reserve/Wildlife Sanctuary. To assure the natural conditions necessary to protect nationally significant species, groups of species, biotic communities, or physical features of the environment where these require specific human manipulation for their perpetuation.

V. Protected Landscapes. To maintain nationally significant natural landscapes which are characteristic of the harmonious interaction of man and land while providing opportunities for public enjoyment through recreation and tourism within the normal life style and economic activity of these areas.

VI. Resource Reserve. To protect the natural resources of the area for future use and prevent or contain development activities that could affect the resource pending the establishment of objectives which are based upon appropriate knowledge and planning.

VII. Natural Biotic Area/Anthropological Reserve. To allow the way of life of societies living in harmony with the environment to continue undisturbed by modern technology.

VIII. Multiple-Use Management Area/Managed Resource Area. To provide for the sustained production of water, timber, wildlife, pasture, and outdoor recreation, with the conservation of nature primarily oriented to the support of the economic activities (although specific zones may also be designed within these areas to achieve specific conservation objectives).

IX. Biosphere Reserve. To conserve for present and future use the diversity and integrity of representative biotic communities of plants and animals within natural ecosystems, and to safeguard the genetic diversity of species on which their continuing evolution depends.

X. World Heritage Site. To protect the natural features for which the area was considered to be of World Heritage quality, and to provide information for world-wide public enlightenment.

(adapted from IUCN, 1984 and currently under revision).

While a reasonable number of protected areas have been established in the tropics, many more are needed; and by themselves, protected areas will never be able to conserve the species, genetic resources, and ecological processes they were established to protect. The best (though admittedly idealistic) answer to this dilemma seems to be to select and manage protected areas to support the overall fabric of social and economic development; not as islands of anti-development, but rather as critical elements in the fabric of the regional landscape. Through a planned mix of well-protected national parks plus other types of reserves which permit some human use, amidst productive forests, agriculture and grazing, protected areas can serve people today and safeguard the well-being of future generations (McNeely, 1985).

6. A STRATEGY FOR SELECTION OF SITES FOR PROTECTED AREAS

A new publication, "Managing Protected Areas in the Tropics: A Manager's Handbook" (MacKinnon, *et al.*, 1985), discusses the various considerations involved in selecting a system of conservation units for a country. In addition to biological diversity and species considerations, these include criteria for tourism, hydrology, geography, politics and management. Only biological diversity criteria will be discussed here, though it is recognized that the other considerations must also be addressed if conservation of biological diversity is to be effective.

6.1. Genetic and Species Considerations in Selecting Sites for Protected Areas

To better conserve the diversity of the world's variation of biomes and species communities involves determining biogeographical divisions and then selecting protected areas from among the best available examples of each. Selection will favour large, less isolated examples which are expected to be richer in terms of species and more stable in terms of retaining the species they contain. Selection will tend to favour areas of high endemism or distinctiveness.

Species do not live in isolation, they live within communities and in ecosystems. It has become well accepted that we should save species primarily through habitat protection and select our reserves on the basis of representational coverage of habitat types. If we did this perfectly, most species' needs would be met but in fact our classification of habitats is neither consistent nor always adequate. It is often more practical to select protected areas on the basis of which key species they harbour; in any case this method is a useful independent check on the biogeographical approach.

Selection of reserves on the criteria of species presence is useful for several reasons:

-- It identifies areas which require urgent protection.

All ecotypes deserve protection but those whose conspicuous species are disappearing before our very eyes are obviously in need of more urgent action.

-- Use of species criteria independently checks and complements the reserve coverage achieved by the biogeographical approach.

From a biogeographical approach we might conclude that we need to protect a sample, for instance, of Javan swampy lowland forests. From species considerations we decide that we must have a reserve to save the last Javan rhinoceros. We combine the two approaches by protecting the last rhino locality as an example of swampy lowland forest, and this is a sensible choice for other reasons. Any examples of lowland swampy forest where rhinoceros are not present are lacking a major original ecological component and, irrespective of habitat condition, are less good examples of the original habitat type.

-- Focussing on key species gives a good indication of the effectiveness of management.

An area may be selected because of its basic habitat type, identified by its dominant vegetation, but it may be failing as a protected area because it is losing many other species unnoticed. Attention to the fate of the rarer species will give a good indication of management success. If the most conspicuous rare species cannot survive, then there is something wrong with the design or management of the reserve which managers must try to rectify.

-- Species provide a focal point or objective that people can readily understand.

Local government officials and local people want to understand the point of a reserve. They cannot appreciate the need to preserve some minor biogeographic subdivision of what to them is just "bush" or "jungle". Nor does it mean anything to them that 5% of species in this habitat are quite distinct. What they can understand is that this is the only place in the whole world where you can still see a giant peccary or lion-tailed monkey.

-- Species have an appeal which wins sympathy, an important factor in raising public awareness and helping fundraising.

Making the tiger -- India's most well-known and evocative species -- the focus of the Save the Tiger campaign helped raise more support and funds for conservation than a general campaign on Indian wildlife could ever have done. In the name of the tiger a wide range of reserves was established in many different ecotypes, protecting examples of many of India's most beautiful wild areas and a vast range of plant and other animal species.

-- Species lists for proposed protected areas provide hard data to back up the biogeographical approach. What is so special about this particular area? What animals or plants does it harbour?

Conservationists try to reduce loss of living resources with the claim that preserving biological diversity helps safeguard the sustained benefits we derive from wild species. Clearly not all species are equally valuable to man and we must give selective bias towards those of known value or species which have been identified as having future potential. Such species would include:

-- wild plant species related to man's domesticated food crops;
-- wild relatives or forms of domestic animals;
-- species with recognized potential for domestication;
-- species harvested from nature for food; wild fruits, bush meat
-- species harvested by man for other forms of utilization; e.g. for dyes, medicine, etc.
-- species whose value for food or other useful products is increasing due to increased rarity;
-- fodder plants for domestic animals;
-- animal species which are useful research models for studies of human behaviour and physiology such as our nearest relatives -- apes and monkeys;
-- species providing utilized or potentially useful drugs;
-- species vital for fulfilling functions on which other harvests depend, e.g. pollination by bees and bats, natural control of pests, etc.;
-- species with capacity to improve soil structure, stability or fertility;
-- species with a high capacity to modify their environment;
-- species with specialized tolerance to extreme living conditions -- to salinity, temperature extremes, deep shade, drought, fire, wind.

Clearly in many regions our knowledge of individual species is insufficient to allow us to make such judgements about species values. Moreover some species of no current recognized value to man may be found to be valuable in the future so it is important to preserve genetic distinctiveness per se. Other things being equal, priority should be given to species that are endangered throughout their range and to species that are the sole representatives of their family or genus. Species not known to be threatened but with highly restricted distributions should be closely monitored and protected within protected areas wherever possible.

By protecting useful species (and their relatives) and a wide range of genetic variation we maintain the genetic diversity from which breeders and geneticists can select for improvements to produce future strains more specifically adapted to man's particular needs. To this end the idea of genepool reserves has been developed (see section 7.7. below).

6.2. Implications of island biogeographic theory in selecting areas for protection

Island biogeographic theory is concerned with the distributions of plants and animals on oceanic islands and island-like areas on the mainland such as mountain tops, lakes and isolated forest patches (Diamond, 1984). It has been found that the number of species and, to a certain extent, the actual species inhabiting islands is highly predictable and dependent on the size of the island and its relative remoteness from colonizing sources. The number of species stabilizes when the rate of local extinctions equals the rate of new immigration. The former is related to island size while the rate of immigration depends on the proximity and richness of the colonizer land mass.

According to the theory of island biogeography small protected areas isolated by modified habitats behave like "islands" and will lose some of their original species until a new equilibrium is reached, dependent on the size, richness and diversity of the area, and its degree of isolation from other similar habitats. Larger reserves lose fewer species at a slower rate, but any loss of natural habitat will lead to some loss of species.

An extensive literature exists on the theory of island biogeography and its relevance to protected area design, selection and management. Diamond (1984), Soulé and Wilcox (1980), Frankel and Soulé (1981), Simberloff and Abele (1976), and Wilcox (1984) provide useful synopses of the subject, with particular relevance to ecosystem conservation and the protected area manager. The main guidelines are summarized below (although it should be recognized that the field is a relatively new one and not all conservation biologists would concur).

-- Protected areas should be as large as possible and preferably should include thousands of individuals of even the least abundant species. They should be of a compact shape with biogeographically meaningful boundaries. For example, watershed boundaries are preferable to rivers, which often bisect essential bottom-land habitats of a range of species. Where a distinct vegetational type, such as a forest patch, is to be conserved it may be necessary to include the whole ecotone and a buffer of the neighbouring habitat type. So far as possible a protected area should include the year-round habitat requirements of as many of the native animals as possible.

-- Protected areas should encompass as wide a contiguous range of ecological communities as possible (e.g. altitude range) since few species are confined to a single community and few communities are independent from those adjacent to them.

-- Precautions should be taken against protected areas becoming completely isolated from other natural areas. If possible, they should be located in clusters rather than dispersed, or they may be joined by corridors of semi-natural habitats.

However, these rules only relate to essentially similar blocks of habitat; for instance, two reserves close together in the same biogeographical sub-division will generally not preserve as many species in total as two reserves further apart and falling in different biogeographical sub-divisions.

While it may be true that no protected area is ever large enough to retain its full biological diversity once it becomes isolated from other similar habitats (and it is as well to realize this and expect some species losses), this does not mean that even small areas will not protect some of the component species, often with reduced niche competition (which can favour rare species). Further, overt manipulation of the ecosystems and their elements can reduce the loss of species, although this may become an on-going exercise which in the long run may be more expensive than acquiring more land at the outset. In any event it is useful to set pragmatic goals which take into account the size of an area and the actions needed to conserve a realistic level of biological diversity they contain, bearing in mind that attempts to determine minimum or optimal-sized areas for protected areas and the genetic diversity they contain are so far at the "research and development" stage (Wilcox, 1984) and results may come too late to be applied.

It is worth noting that biological diversity is not uniformly distributed and we can often recognize "hot spots" such as areas of high local richness or local endemism (Wilcox, 1984). The Amazonian Pleistocene refugia are such an example (Jorge Padua and Tresinari, 1984). Attempts should be made to include these "hot spots" in the protected areas system to get better "value" for number and uniqueness of species protected per area.

A useful general strategy is to include at least one large protected area in each biogeographical sub-division. This should usually include as many ecological communities as possible with omissions and variations being represented in smaller satellite areas.

In selecting areas for protection at the national level there is a need to select sufficient coverage to safeguard against the loss of the biogeographical features being protected due to some natural catastrophe, such as flood, epidemic, earthquake or changing lake levels. This insurance is enhanced if particular biogeographical entities are protected in more than one country as this reduces the risk of their loss through local political strife.

6.3. Reserves for Migrant Species

The special needs of migrant species are often overlooked. Often managers feel that they are not responsible for migrants that visit their areas only in passage or for a few months, and that they are the responsibility of the countries that harbour their breeding populations. However, because migrant species spend much of their lives outside the boundaries of protected areas, often make arduous and hazardous journeys and generally arrive in a weakened physical condition they are particularly vulnerable. Resident human populations also view migrant animal species as a bonus or free resource for exploitation and exhibit complete lack of constraint or responsibility in their harvesting methods. For example, villagers on the north Java coast harvest over one million migrating rails and waders each year for food (Alikodra, 1982).

The importance of migrant species and the responsibilities of those countries in which they settle during the non-breeding season, or on passage to and from wintering grounds has been highlighted by the Migratory Species Convention concluded in Bonn in June 1979.

Each country should make a particular effort to make an inventory of migrant species using its territory, assess the status of these species and whether their particular requirements can be met.

Protective management for migrant species may in some cases involve the establishment of permanent reserves such as the Djoudj Sanctuary on the Senegal delta and the Keoladeo (Bharatpur) National Park in India where tens of thousands of wintering wildfowl congregate on artificial reservoirs. Elsewhere it may be necessary to legally protect migrants, to prohibit hunting of wintering populations or to apply seasonal protective measures to important feeding areas and roosts, which can be used for other purposes during the rest of the year. It can also be helpful to provide grain at migration "stations" or to compensate local landowners for loss of grain to migrating birds, as is done along the geese migration routes on the eastern seaboard of North America.

Long migration routes are often dependent on key transient points where animals stop to rest, water, and feed before continuing their journey. Inadvertent destruction of such key sites, for instance, pollution of a muddy estuary important to migrating waders, can prove disastrous to some species.

7. TECHNIQUES FOR IMPROVING MANAGEMENT FOR BIOLOGICAL DIVERSITY IN PROTECTED AREAS

7.1. General Notes on Management Strategies at the Ecosystem Level

Management of living resources in natural protected areas involves steering the ecosystem. This requires an understanding of ecological principles, an appreciation of the ecological processes operating in the protected area, and the acceptance of the concept that protected area management is a specialised form of land use.

Ecosystem management is such a technically demanding task and enormous responsibility that many people simply back away from the the job and claim that " Nature knows best". This passive attitude, however, is also dangerous. Most reserves are already far too small, too isolated and too affected by man's influences -- historically, directly, or indirectly -- to maintain their original state if simply left alone. Leaving things be may be the easiest and cheapest course to follow but the decision to allow natural processes to continue without interference, i.e. apply a policy of "benign neglect" is itself a management decision and must be taken with as much consideration as the decision to institute manipulative management.

What management is necessary will be determined by the objectives stipulated for the given area. In most cases some active management will be required to reach or maintain these objectives. There is almost nothing in Nature that can be called a "stable environment", even within the large blocks of undisturbed climax rainforest. The elements that managers wish to preserve in protected areas can easily be lost through lack of management simply because the nature of the reserve changes. Sub-climax situations proceed towards climax unless arrested by continuing influences such as cropping, regular burning, landslips and so on. Climax floras age and pass through senescent collapsing phases before the area becomes recolonised by pioneering plants which again pass through long and complex cycles of succession. By the time mature climax vegetation is reached again, if indeed it is ever allowed to do so, the nature of the soil will have changed and the species composition of the new forest will be different from the old.

All areas continue to change as new species are introduced by wind, animals, man or other agency. Other species drop out through local extinction, diseases, pests and other ecological factors. By allowing surrounding habitats to be changed Man has enormously affected the remaining undisturbed patches. Because of the "biological island effect" they will lose much of their original diversity unless artificial ways of maintaining genetic exchange and immigration with outside populations are developed, or buffers or corridors of similar habitats are established.

Clearly a good deal of active management is needed to maintain the qualities managers wish to preserve in protected areas. However it must also be stressed that interference with natural processes is fraught with dangers. Bad management can be worse than no management. It is not necessary to know how a car works to drive it safely but one must know the effects of the different controls on the car's behaviour. So too with ecosystems it is dangerous to play with the controls until the effects are known. Ecological processes are often unpredictable because of their complex interrelationships. Although ecological knowledge is growing rapidly, scientists are still so ignorant of the workings of many tropical ecosystems that it is wise to be cautious.

While no ecosystem is stable on this dynamic planet, some, from a short-term viewpoint, are far more stable than others. One of the basic considerations, *from a management* point of view, is whether the vegetation is in a climax (mature) or early stage of succession.

Thus protected areas in the two most widespread habitat types found throughout the tropics -- rainforests and savannas -- require quite different management prescriptions. Whereas savannas are rather unstable ecosystems balanced by climate, fire, wildlife use and human influences, primary rainforest is a climax situation. In order to conserve a savanna area manipulative management -- controlled burning, regulation of animal populations, cutting of vegetation, etc. -- is essential. In rainforests, on the other hand, little interference is required to maintain the ecological climax and allow regeneration in disturbed areas.

Sometimes management decisions may be crucial in determining whether a unique ecosystem is preserved. For instance a given protected area may preserve the unique vegetation growing on the side of a volcano. But the vegetation is only a transient stage between the last eruption and a future climax stage when the mountain becomes completely reforested so allowing the process of natural reforestation to continue may mean loss of unique species. This can only be discouraged by an active management policy preventing such reforestation. Whether this is an appropriate management policy will depend on the original objectives of the reserve. Was it established to protect the unique flora? i.e. a particular combination of rare species, or to protect the watershed? i.e. the greater the forest cover the better. Was the reserve established for the study of the natural processes of vegetation succession?

Another example: An area was originally a hunting reserve where vegetation was cleared to provide open grassy feeding areas to encourage large game. Later, however, the area is declared a nature reserve with the specified objective "to protect the native wildlife in their natural environment". After a few years of such protection it is noticed that the area is becoming reforested and the number of large mammals is dropping. Since the main management objective was to protect the wildlife and their natural habitats, in this case large mammals and early succession stages of vegetation, the manager should apply active management measures such as clearing or burning shrubs and bushes to reopen the grazing areas. Habitat management will probably be restricted to selected areas of the reserve and elsewhere the vegetation will be allowed to evolve naturally towards a climax stage. The matter would have been even clearer if the original objective of the reserve had been phrased "to protect the characteristic local wildlife, particularly the high density of large mammals, in as natural a habitat as possible".

Once it is decided that active management is necessary to maintain an area in an early succession stage of vegetation much consideration should be given to selecting the most suitable means; cutting, burning, grazing, selective ring-barking, etc., are all possible methods. It is safest to test the selected procedure on small scale experimental plots before applying it over the whole area.

As noted in section 2, there exist some 1,420 protected areas in the tropical realms. It is widely accepted, however, that many protected areas exist on paper only; most suffer from what has kindly been termed "benign neglect", and others are threatened by a variety of factors that are affecting their integrity. IUCN has recently completed a survey of threatened protected areas of the world, and published a list of 43 threatened areas of which 35 were in the tropics. Another signal that we cannot assume that once an area is protected it will be secure is the placement of three areas on the List of World Heritage in Danger compiled under the World Heritage Convention. (For a graphic portrayal of field conditions common in a typical African protected area see Thorsell 1982, and Mosha and Thorsell, 1984).

Protected area management can be defined as the skillful treatment of a reserve including protection, policy development, planning, research, maintenance, visitor use, staffing, and administration. As protected areas are managed for a variety of purposes (see section 4), it is not easy to isolate those elements of management that only relate to biological diversity. There are, however, eight specific areas in which techniques for managing biological diversity in protected areas need strengthening. Although many reflect constraints on park management in general, the emphasis here is given to methods and actions of particular concern to biological diversity.

7.2. National policies for protected areas

Few developing countries have developed policy-level strategies for integration of protected areas into national development plans, or for operation of the protected area system itself. Without such an overall policy structure, protected areas become isolated from the overall development process and languish in the lower priority backwater government departments.

One activity which addresses this problem is the development of National Conservation Strategies (NCS) in which general policy statements on the role of protected areas within the country are developed. IUCN is working with 12 tropical countries at present in developing such strategies and many more are being proposed. These strategies are ideal vehicles to present the case of biological diversity. (Both Nepal's and Zambia's NCS reflect this).

At the national level few protected area agencies have developed their own system plans in which the total system of protected areas in a country is analyzed in terms of the orderly allocation of wildland resources. The method for undertaking these system strategies has been discussed by MacKinnon et al., (1985 in press), McNeely, Miller and Thorsell (1985, in press) and Thorsell (1983) and will not be reviewed here. Brazil, Indonesia, and Dominica are three examples where system plans have been undertaken.

Another need at the policy level is for national operational policy guidelines for the protected area system, such as have been produced in most developed countries and as outlined in a recent FAO manual (1984). Once again, specific policies and guidelines for maintaining biological diversity are contained therein.

7.3. Management plans for protected areas

Few protected areas in the tropics have management plans to guide and control the protection and use of specific areas. This has been identified as a major constraint to management in almost all tropical countries (see Snidvongs, 1984; Thorsell, 1984). Without properly prepared management plans most areas suffer from inappropriate development, sporadic and inconsistent and ad hoc management, and lack clearly defined management objectives. Management plans also act to review the existing data base available, to encourage resource inventories and to define research and monitoring programmes, all of which are activities basic to maintaining the integrity and diversity within existing areas.

IUCN has long supported the development of management plans for protected areas and has developed a standardized approach to their preparation based on a workshop at the World Congress on National Parks in Bali in 1982. This procedure, oriented to the realities and sensitivities of tropical developing countries, is currently being applied in six protected areas (Amboseli, Kenya; Simen Mountains, Ethiopia; Sapo, Liberia; Khao Yai, Thailand; Sinharaja, Sri Lanka; and Amboro, Bolivia). Details of the methodology are contained in MacKinnon et al., 1985 (in press), and Thorsell (1984).

7.4. Evaluating protected area management effectiveness

Monitoring the success or failure of efforts in management is an often overlooked phase in the overall management process. Yet these efforts are crucial in determining how well existing areas are meeting their objectives and concomitantly allowing managers to judge how well biological diversity is being maintained. It also reminds managers of the full range of management strategies that are involved.

Approaches to evaluation are discussed in MacKinnon et al., (1985, in press) including the use of a standardized questionnaire that has been developed and field tested by CNPPA. This checklist approach has proved useful in the few areas where it has been used but needs to be refined and applied more widely. A copy of the questionnaire is given in Appendix I. (This has been field tested in Arusha National Park, Tanzania -- see Thorsell, 1982).

7.5. Developing the human capacity to manage protected areas

Trained personnel are essential to success in effective management of protected areas. As Miller (1978) has noted: "In the final analysis, the ability of a country to implement a national park programme in any practical way will depend upon whether it can obtain and employ men and women capable of selecting goals, designing plans to meet those goals, and then actually implementing the plans to actually achieve those goals".

Training has been identified as a major constraint on conservation management in the World Conservation Strategy, various reports of the UN's Joint Inspection Unit and more specifically in various protected area action plans developed by CNPPA. Training is required at many different levels (decision-making, senior management, professional, and technical) and is carried out in many forms (workshops, conferences, study tours, short courses, staff exchanges, in-service courses, colleges and universities).

For some 50 tropical developing countries, protected area managers depend upon six techical colleges that have been established to meet regional training needs. These are located at Bariloche in Argentina, Centro Agronomico Tropical de Investigacion y Ensenanza (CATIE) in Costa Rica, Ecole de Faune in Garoua, Cameroon, College of African Wildlife Management in Tanzania, Wildlife Institute of India in Dehra Dun, and the School of Conservation Management in Bogor, Indonesia. Programmes at at least four of these centres are in need of external support and all need strengthening to add biological diversity concerns in their curriculum.

The constructive efforts played by the International Affairs Division of the US National Park Service and US Fish and Wildlife Service have been of particular value in training, as have those of the US Peace Corps (see Wetterberg, 1984). Training requirements for South America have been outlined in a detailed strategy prepared by Miller (1982). Unfortunately, there has been little follow-up on the recommendations.

7.6. International assistance for protected area operation and management

Of the 118 nations classified by the UN as developing countries, less than half have properly constituted national parks. Of these, some possess parks which are among the finest in the world, with well-established professionally staffed organizations to administer them. Such countries need neither external assistance nor advice; on the contrary, they could usefully teach much to others in the field of resource management. Unfortunately, these nations are in a minority and the majority, especially among the least developed countries, either have no parks as yet or have areas which do not conform to internationally accepted criteria.

This may be due to a variety of reasons: lack of suitable areas or the lack of trained personnel to run them; political instability and consequent security problems in the remoter areas which have the best potential for national parks; lack of government recognition of the need for parks or low priority in comparison with other development needs, such as irrigation schemes, schools, hospitals.

It is all very well to stress the importance of biological diversity and the need for national parks and reserves to developing countries but the international community must understand their problems and be prepared to provide effective assistance where needed. Mechanisms must be developed for the fair sharing of costs and benefits associated with protected area management, both among nations and between protected areas and adjacent communities. The World Heritage Convention implemented by Unesco is one way of sharing the costs but has a very limited budget and covers only relatively few areas. Areas which are really worthy of development as national parks are part of an international heritage as well as being of value to the country concerned, and it must be recognized that the poorest countries cannot reasonably be expected to develop parks to the requisite standard without substantial external support.

Some countries which now have national parks and the qualified staff to manage them may sometimes need occasional support and assistance in certain specialized fields such as research, interpretive programmes, legislation, preparation of management plans or the special difficulties to be resolved in the planning of marine parks. Such needs can best be met by short-term projects or consultancies, preferably employing suitably-qualified people from neighbouring countries or consultants with past experience in the region. Assistance and funding can be requested from many sources: multilateral organizations; non-governmental organizations with international programmes; international bilateral assistance organizations; national governmental agencies with international programmes; volunteer organizations; international banks and other sources such as corporations and trusts.

7.6.1. Forms of assistance

Needs for international assistance vary considerably among countries. International assistance is usually available in one of the following categories:

-- Supplies and Equipment

In some countries the most serious limitation to effective management of protected areas is simply the lack of supplies and equipment. Purchases of overseas technical equipment is difficult for many government departments and locally purchased items may be two or three times their realistic cost. Donations of equipment can sometimes be cleared duty free by the recipient department or project. Care must be taken to ensure that such equipment is locally appropriate and that post-operative maintenance aspects are considered.

-- Technical Assistance and Specialized Consultancies

Temporarily-assigned experts or consultants are frequently engaged to review government projects and policies or prepare special plans and reports. There are some dangers, however, in countries developing too high a reliance on overseas experts. First, the foreign experts sometimes fail to adapt their ideas and standards to the particular culture and economic level of the country concerned. There is much energy wasted on the production of excellent reports and plans (including many national park management plans) that are too technically advanced for implementation in the country concerned, or which are never translated nor locally assimilated. There is also the problem of never learning to do the job on your own so long as you can get someone else to do it. Developing countries must develop their own competence for at least the routine technical aspects and should ensure that all foreign consultants are supplied with enthusiastic local counterparts who can absorb technical skills by working with the expert.

Experts are also often brought in by park directors to get plans or policies passed by central government which are given greater credance and acceptability simply because they were produced by "special consultants". This is just a matter of human psychology "The grass always seems greener on the other side of the hill", but it is sometimes a valid justification for international assistance nonetheless.

-- Training Programmes

Building up technical knowhow depends on training. Counterparts can learn skills and techniques during their working assignments with visiting experts but this rarely gives them the range of theoretical and practical training needed to fulfil the wide range of functions involved in management of protected areas. It is necessary also to have more formal training opportunities. International assistance has been provided for a number of training schemes including:

-- Help in establishing regional training centres. These schools provide excellent broad training programmes for senior and middle management staff. Such schools not only provide valuable training at the field level but are a useful forum for exchange of ideas and views from individuals working with similar problems throughout the region, though the protected areas for which they are responsible may cover very different habitats.

-- Providing overseas instructors for local training schools and courses. The cheapest way to teach new techniques to a large number of people in a country is to train them locally, importing instructors as necessary.

-- Providing overseas fellowships and scholarships for individual students to undertake training abroad. Where specialized knowledge is needed by only a few people this is cheaper than organising local training. Many American universities in developed countries, e.g. Michigan and the State Universities in the West, have relevant higher degree courses.

-- Providing funds for study tours and international seminars. Senior staff who cannot be released from their important duties for too long can often benefit greatly by attending special study tours or international seminars, e.g., Australian Summer School of National Park Management and the annual International Seminar on National Parks and Equivalent Reserves held in North America.

-- Execution of Projects

International assistance is sometimes sought to help execute special projects or operations. This is very useful if the operation is a specific one or if in execution the local staff learn how to perform similar follow-up projects themselves. For example, a veterinary scientist was lent by the Namibian Government to supervise the darting and translocation of a herd of elephants in Sri Lanka where his considerable experience in such operations greatly contributed to the success of the project.

Maintaining long-term experts to help run or supervise protected areas is rather costly and can undermine the country's own capabilities. Alternatively, the employment of overseas volunteer workers from such agencies as Peace Corps can provide very useful and well-motivated personnel who are often able to develop very good rapport with the technical officers and labourer levels of project execution.

-- Research Assistance

Foreign scientists, when partnered by local counterparts, can contribute to the development of improved management techniques. Protected areas in the tropics provide scientific laboratories of great interest to many temperate world researchers and such research is an area where international cooperation is common. Each country must make an effort to pioneer its own management methodology, as well as liaise and compare findings with reseachers in other countries, if it is to make the best use of its renewable living resources and protected areas.

7.7. The special case of protected areas as genebanks

Conservation of gene pools is a primary objective of several management categories. *In situ* genebanks are areas established with the purpose of conserving wild gene pools of wild economic species, or as zones within existing protected areas. Adoption of either alternative will depend on the locations of the gene pools to be conserved and on the social, economic and political practicalities of each situation.

Protected areas established as *in situ* genebanks should have as explicit objectives the maintenance of wild genetic resources and provision of information on and access to those resources by *bona fide* researchers, breeders and *ex situ* genebanks. If the genebank is part of a protected area with other objectives, the areas required for gene pool conservation should be zoned for gene pool conservation as the primary use. Other uses should be controlled so that they do not conflict with gene pool conservation or should be excluded from the genebank zones altogether.

Each *in situ* genebank should have a list of the species (and populations within that species) it maintains. The list should indicate the locations of the species, including map grid references. Detailed information on gene pools (characteristics, habitats, locations) should be added to the list as research makes it available. As far as possible, data on phenology (e.g. time of flowering, fruiting, seed maturation) should also be kept. These are valuable aids to germplasm collection and exchange. Ideally, for plants, there should be a herbarium sheet for each species or variety listed (again, giving the precise location). Many genera are taxonomically confusing and the species within them difficult to identify. Herbarium records serve to validate the species list and can save unrewarding trips into the field looking for species that have been misidentified.

There should be an arrangement with the nearest appropriate *ex situ* genebank (this might be in an agricultural research station, a botanical garden, or both) to provide standby storage of germplasm collected in the protected area and to act as a link with the community of genetic resource users. There may also need to be an arrangement with the nearest herbarium to house voucher sheets for the genebank's plant species list. An active partnership with universities and colleges would be extremely valuable. Species lists could be compiled and herbarium specimens collected at very low cost if they were done as directed studies and thesis topics, as could more advanced research on gene pools.

General guidelines for management of *in situ* genebanks can be found in Prescott-Allen, 1984(a). These have been further amplified and applied to northwest South America in Prescott-Allen (1985).

7.8. Developing management techniques for rare and endangered species in protected areas

Management for rare and endangered species is a major element in biological diversity conservation and many protected areas were, and continue to be, established with this need in mind. Clearly the conservation of species populations may demand different strategies from those appropriate for the protection of ecosystems.

There are three main factors causing an animal species to become rare or in danger of extinction: loss and destruction of vital parts of its habitat; unusually high mortality or low reproduction; climatic, geological and evolutionary changes.

All these causes may act concurrently.

The following management measures can be considered to help a declining or dangerously small population of a species of special interest (from IUCN, 1985, in press):

-- Stop habitat destruction, which is without doubt the primary cause of wildlife extinctions. In practice, this means enforcement of conservation laws, renouncing logging concessions, stopping shifting cultivation, etc;

-- Protect the species' habitat: habitat protection includes the control of tree felling, logging, collection of other forest produce, forest fires, clearing and burning new farm land, etc. In certain cases, the habitat may require restoration by artificial means, i.e. seeding, planting or other propagation methods of vital foodplants, clearing and maintenance of grazing grounds.

-- Extend or increase protection to migration corridors, breeding sites, or roosts (for instance, provision of nest boxes).

-- Habitat management -- this includes all forms of manipulation of the vegetation to make it more suitable for the species in question. For grazers and browsers this might mean preventing woodlands from reaching climax or even maintaining cleared or burned areas of grassland as feeding areas. It can include planting or removing particular plants. For instance, a method called "liberation thinning" was proposed in Sarawak;

Malaysia, whereby large timber trees in reserves were to be ring-barked to kill them so that the smaller fruit trees which provided the bulk of the food for the arboreal animals would be "liberated" and able to grow faster and be more productive (Proud and Hutchinson, 1980).

- Protection of the endangered species: improve patrols, control illegal hunting and trapping, special intensive anti-poaching measures - for instance actually guarding animals by day and enclosing them at night as had to be done with white rhinos in Kenya's Meru National Park.

- Reduce predation of the young by physically excluding potential predators, e.g. by fencing turtle nests to prevent egg predation by monitor lizards and wild pigs.

- Headstarting -- this can include artificial hatching of eggs and rearing of young to reduce early mortalities, but there may be difficulties in releasing the young again as many species need to imprint on either their parents or their birthplace. This method has been successfully applied to megapode nesting areas in Sulawesi.

- Provisioning -- providing extra food, water, minerals at salt licks, shelters or by planting favourite food plants. This is often quite effective and is usually only necessary for a short critical part of the year. Problems may arise if this results in causing unnatural concentrations of animals which render them vulnerable to predation or disease. It may also cause local damage to the vegetation, as has occurred at many park waterholes in Africa.

- Control or eliminate animals (exotic or non-indigenous animals) which may severely disturb and compete with the indigenous community.

- Control or (better) eliminate feral animals, (i.e. domestic animals that have run wild) as they may kill or compete with wildlife (for example, the goats on Galapagos Islands).

- Reducing the levels of predators is only justifiable if the predators are exotics. Predation can seldom be blamed for the extermination of a species, for the simple reason that when the ratio of "hunting success" to "hunting effort" becomes too low, the predator chooses another, more abundant and easier prey species. Typically the local predators are the most threatened species of the ecosystem. Usually predators are actually helping to maintain optimal density and good health in a prey species by removing sick animals from the population. Overkilling of wolves in Alaska resulted in a drop, not an increase, in the numbers of their main prey, the caribou.

-- Reducing competitors is a rather drastic action but may be justifiable if the competitor in question is an exotic or feral species or present in unnaturally high numbers or to save an ecotonal species (for instance, the introduced Kikuyu grass in Hawaii Volcanoes National Park).

-- High mortality, whether caused by disease, predation, subsistence, hunting or poaching, (except for commercial reasons) has rarely led to extinction of a wildlife species. Even an epizootic like rinderpest, which severely ravaged the populations of African buffalo at the turn of the century, did not cause the species to become endangered. However, epizootics may become an acute threat to a species already rare or endangered, particularly when the disease originates in a population of a species sharing the habitat with the rare species.

-- Where suitable habitats are available individuals of endangered species should be moved to them to avoid the risks of having only one, or a few populations, of a particular species. Where possible this risk should be spread internationally to avoid extinctions due to political unrest.

-- Restocking can be used to re-establish a population in areas where it has gone extinct or is very rare. This involves relocation of individuals from wild stock elsewhere or release of captive-bred animals. Before boosting populations by restocking the manager must first discover why the original population was dwindling. There is no point in raising the population level if the habitat cannot support greater numbers.

-- Breeding in captivity, seed and sperm banks. A last means to save a species from extinction is controlled propagation of captive individuals and subsequent re-introduction of captive-breds in protected, appropriate habitats. The success stories of the NeNe goose (Hawaii), Arabian oryx (Oman) and white rhinoceros of Natal, are well-known. Captive propagation should be carried out in a safe place, for instance in zoos of good reputation or institutions especially equipped for propagating endangered species. Captive breeding may also be done on site, in the species' own habitat, under rigorous protection. Some problems may be met in capturing wild animals as breeding stock, e.g. shock, stress, mortality during immobilization and transportation. Also the animal's physiology and behaviour may change in captivity and may have unfavourable effects on the breeding success.

-- Climatic, geological and evolutionary changes. In general, these changes take place very slowly. Volcanic eruptions or cyclic climatic changes may temporarily cause excessive mortality but such changes have rarely caused a species to go extinct. Long-term climatic changes have much more drastic effects, but like the course of geological and evolutionary changes, they are irrevocable and cannot be "managed" or stopped. Their effects may sometimes be alleviated, e.g. by provisioning during droughts.

7.9. The Special Case of Protected Areas and Island Ecosystems

Islands have several inherent advantages as reserves because they have clear boundaries, have already developed a balance between their size and species number, cannot be easily encroached and are relatively independent ecological units.

They also have a number of disadvantages. Islands do not contain and cannot protect anything like as wide a range of species as a piece of comparable habitat of similar size on the adjacent mainland. Islands show rather fast species turnover, i.e., the species composition of the island changes so the particular species of interest for which the reserve was established may be lost through natural processes. Moreover, deliberate and unintentional introductions of man's commensals and other species can be disastrous to island floras and faunas. The islands of Hawaii have lost more than half of their original endemic species due to incautious introductions of other animals and plants.

Small islands or isolated continent-sized islands, such as Madagascar and Australia, or isolated waterbodies, e.g. Lakes Malawi and Tanganyika, are often the homes of rare endemic species and archaic or primitive forms. These species have radiated to fill the available niches and have survived because of the failure of more advanced species to reach the island, reduced niche competition and the general absence or small size of predators on small islands. Under such circumstances the introduction of just two domestic cats can be a disaster.

Islands may be useful as isolated "pens" where rare species facing extinction on the mainland can be released in the absence of competitors and predators and given high levels of protection in the hope that the population can be nurtured back to a higher level. This technique has been used very successfully to save the rare kakapo, New Zealand's ground-living parrot, and the Kri Kri ibex released on several islands of Crete. Such experiments have considerable hazards, however, and like all manipulative management should be attempted only after serious ecological investigation.

In practice the general management of island reserves is relatively simple and is best illustrated in the management techniques developed for measures taken to protect the Galapagos National Park. The following general guidelines are offered for island reserves:

-- Whenever possible the entire island should be included in the reserve.

-- Ideally no residents should live in the reserve. If possible no staff should live there either, but they should visit and patrol on a regular basis.

-- Very strict regulations should be enforced to prevent the introduction of exotic animals or plants. If introduced species have already reached the island and are a threat to the original species they should be eradicated.

-- Where the entire population of a species, or valuable subspecies, occurs on a small island, or is confined to one continuous habitat patch on a larger island, it is advisable to transfer part of the population to a second suitable site to avoid the risk of an epidemic or natural disaster decimating the population, i.e. "don't have all your eggs in one basket".

-- If possible, ensure that there is some natural or semi-natural habitat on the mainland closest to the island to act as a colonising source for well dispersed species. Where there is no such habitat left on the nearby mainland the island may suffer from species losses unless immigrants are introduced artificially.

-- Efforts must be made to prevent fishermen and others camping on the island. Islands in the tropics are highly susceptible to fire, vegetation removal and disturbance of nesting birds.

- Survey the marine or aquatic potential around the island. If the surrounding waters have high conservation value they should be included in the reserve, or as a buffer, to increase the overall use and benefits of the reserve. (For further guidelines on the management of coastal and marine areas see Salm and Clark, 1984).

8. ACTION RECOMMENDATIONS

Recommendations on actions that various US institutions, as well as development agencies, banks and non-government groups can take, have been proposed in detail in two official US Government documents: Conserving International Wildlife Resources: The US Response (1984) and in US Strategy on the Conservation of Biological Diversity (1985). Both of these reports had earlier precedents in the form of The Preservation of Biological Diversity: A Survey and Recommendations (Nature Conservancy, 1975) and Proceedings of the US Strategy Conference on Biological Diversity (1981). IUCN is in general agreement with the thrust of the whole range of recommendations contained within these important documents as well as with those made by the World Resources Institute Biological Diversity Working Group (1984) and the National Resources Defense Council (1985).

Rather than repeating the message contained in the above policy papers, this section makes specific recommendations based on the material contained within this report and also presents, as an illustration, an action plan for protected areas in general as well as for one of the most important tropical realms. It is worth emphasizing that most of the techniques for undertaking the following tasks are already available, so the main requirement is to develop ways and means by which known conservation technology can be applied to real on-the-ground problems. This application in turn relies on political will, trained manpower, and financial support.

8.1. Recommendations

The following 18 recommended actions are based on the discussions in sections 1 to 7 of this report. Priorization is a difficult task and two categories (urgent and high) are noted at the end of each action.

- Reinforce efforts to strengthen the global data base on species and protected areas such as being developed at IUCN's Conservation Monitoring Centre at Cambridge. CMC now has a professional staff of 20, but has insufficient resources to cope with the task that is required. The CMC data base has many applications to on-going work of USAID, the State Department, and US Department of Interior and greater use of the facility is encouraged. The US National Park Service and USAID are already using the system for several specific products, but a much greater expansion is called for. One possibility which is worth considering is to develop an on-line capacity for USNPS, as well as for development banks and other data centres. In addition, all US missions abroad, should hold up-to-date information on genetic resources, protected areas and threatened species of the particular country. Such information could be provided by IUCN/CMC on a subscription basis and would enable the US mission in any country to be aware of the major conservation issues in the country and be in a position to provide data to national conservation efforts. (Priority: Urgent).

-- Tropical countries must be given every encouragement to establish more and better-managed protected areas in order to complete the biogeographical coverage of representative samples of the world's ecosystems. This effort needs to be based on national-level reviews of the adequacy of current coverage and in most parts of the world must be done urgently, before land use options are foreclosed. IUCN has already developed the methodology for such reviews (MacKinnon, 1985), but the methodology needs to be disseminated more widely and adapted to local conditions; workshops in key countries could be organized by USAID, USNPS, USIA, US MAB, and other relevant governmental and non-governmental organizations. Assistance in conducting these reviews from qualified biogeographers and park planners from various US universities, institutions and in the US Department of Interior should be made more widely available. (Priority: Urgent).

-- Tropical countries should also be encouraged to employ a broad range of protection categories to give their systems greater flexibility, to give at least some protection to areas that can never be acquired as totally protected areas, and to help integrate conservation more closely with development and production. Utilization in protected areas, however, must be undertaken with utmost care to ensure that biological diversity and other vital protection needs are not compromised. The USAID-sponsored "Wildlands and Human Needs" project with WWF-US is an excellent example of the type of project that can be very effective in expressing these concerns, and other such efforts should be implemented elsewhere in the tropics. (Priority: High).

-- IUCN's current reviews of the adequacy of protected areas in sub-Saharan Africa, Oceania, and tropical Asia will be valuable tools for identifying gaps in coverage and regional priorities (at a gross, continent-wide scale). The approach should be applied to other tropical regions as well, as in the IUCN proposal on the Neotropical Realm, which has been submitted to USAID. On the basis of the continent-wide reviews, USAID, in cooperation with USNPS and USFWS, should promote national systems reviews in high priority countries, and should be encouraged to complete their preparation of Country Environmental Profiles as required by Congress. (Priority: High).

-- The maintenance of biological diversity should be seen within the broader scope of protected area management and wildland conservation management. This will involve consideration of socio-economic conditions of local people, and integration of protected areas within the fabric of the regional landscape. USAID, as well as the development banks, should ensure that a protected area component is built into all development projects, as has been done in the Mahaweli scheme in Sri Lanka and the Dumoga project in Indonesia. NGOs active in conservation could help to promote action by the development banks. Congress could make the consideration of impact -- both positive and negative -- of major development projects a precondition to providing funding authorization for World Bank, Asian Development Bank, and other major funding agencies which receive public funding. (Priority: High).

-- Along with regard for impacts on protected areas from development projects, consideration should also be given to impacts of protected areas on their surroundings, particularly those reserves that are vulnerable to destruction and disturbance due to poverty of local people. Such buffer zones should be considered as priority locations for development projects aimed at raising local living standards and taking pressures off protected areas. One of the functions of economic development plans, intersectoral conservation policies and national conservation strategies should be not only to identify those development projects that require protected area components but those protected areas that require development components to ensure their objectives are achieved (see Panwar, 1985 for an illustration as to how this is already in effect in India). (Priority: Urgent).

-- A key vehicle to incorporate policy concerns for biological diversity into the development process is through their inclusion in National Conservation Strategies (NCS). The preparation of NCS needs to be initiated in more tropical countries and provision made for inclusion of these aspects. Current USAID support for preparation of an NCS for Nepal provides an example which should be replicated in many other countries where specific proposals have been submitted. (Priority: Urgent).

-- Both operational policy statements and management plans are key constraints on protected area management in tropical countries and further efforts are required in order to prepare these. The International Affairs Offices of both the US National Park Service and the US Fish and Wildlife Service have much experience in this type of technical assistance and should be given greater allocations by Congress in order to expand and better coordinate their activities. (Priority: Urgent).

-- The various efforts of the US National Park Service and US Fish and Wildlife Service International Affairs Offices, particularly their role in training, is endorsed and should be extended further, as outlined in detail in the "Wildlife Report" (1984), Wetterberg (1984), and by the Natural Resource Defense Council (1985). The established training facilities at Harpers Ferry and at Grand Canyon already cater to limited participation from developing countries and this could be expanded considerably at little additional cost. In view of the important work carried out by the International Affairs offices, their status within the Department of Interior should be upgraded to a higher level. (Priority: High).

-- Particular emphasis should be given to strengthening the training efforts in the six regional parks/wildlife training colleges. Exchange programmes and linkages with US Federal and State park agencies and technical colleges, supported by USAID, is one means of assuring this. Provision of educational materials, teaching aids, and instructors, as was carried out by the USNPS in Tanzania, is another. (Priority: Urgent).

-- The International Seminar on National Parks Management, held each August under sponsorship of USNPS, Parks Canada, and the University of Michigan, has been an extremely useful means of providing training to upper- and middle-level protected area managers. A similar seminar is being developed by USNPS and NOAA for coastal and marine protected areas. These efforts should be continued, a biological diversity component added, and the possibility of developing similar seminars in specialized fields, such as public relations and interpretation, should be considered. (Priority: High).

-- In some countries, there is still a need for trained manpower at the higher levels. Support through such programmes as Fulbright Scholarships for individuals seeking M.S. or Ph.D. degrees in fields directly relevant to protected area management would be extremely useful. A major effort to identify, develop, and use a network of land-grant universities with strong natural resource management programmes to train promising young managers from developing countries would pay great dividends in the coming years. (Priority: High).

-- International assistance for management of national parks and protected areas needs to be increased many fold in five areas: supplies and equipment; technical assistance; training; research; and project execution. USAID, the Peace Corps, and the Department of Interior all play critical roles in providing this assistance. The World Wildlife Fund and other NGOs provide significant levels of support in this area, but far more can be done at the government-to-government level. Peace Corps especially, is particularly cost effective and a policy shift to resume the importance of their work in the environmental area is suggested. (Priority: Urgent).

-- Support for implementation of the World Heritage Convention is a particularly useful and effective means to channel assistance to some 40 key areas in the tropics which are on this select list. The support of the US (through the State Department) for this Convention is critical and should be resumed and greatly increased. (Priority: Urgent).

— The in situ gene bank concept needs to be field-tested, along with parallel activities in undertaking species inventories for all protected areas. The activities of the National Academy of Sciences in sponsoring taxonomic work in tropical countries and of the Smithsonian Institution's work in applied tropical biology are of particular note and should be given every encouragement. Similarly, the work of the various botanical gardens (e.g. Missouri), zoological societies (e.g. New York), and private voluntary organizations (e.g. World Wildlife Fund) in tropical countries provide a foundation and a vehicle through which much of this work can be sponsored (assuming that western technology transfers are modified to relate to tropical settings). (Priority: High).

-- Further application in demonstration areas of the various techniques available for protecting rare and endangered species. The US Fish and Wildlife Service are world leaders in this field and should be encouraged to adapt their techniques for use in the tropics. Key Fish and Wildlife Service documents should be translated into other languages, particularly Spanish, French, Swahili, Chinese, and Malay/Indonesian. (Priority: High).

-- Efforts to demonstrate the economic and importance of protected areas need to be better developed. In many countries, protected areas are considered "set aside" rather than being "managed effectively for the benefit of society." The benefits of protected areas can be quantified, but few efforts have been made in this direction. The National Academy of Science could provide the basis for a major study on the economics of biological diversity. (Priority: High).

-- Efforts towards public awareness of the importance of protected areas and biological diversity needs to be greatly expanded. While this is properly the task of the governments directly involved (along with local PVOs), the US Government could provide support through sending US and other experts on speaking tours, inviting the Department of Interior to prepare exhibitions for use in developing countries, circulation of films to relevant colleges, universities, and training institutions, and other means. Involving US-based PVOs, such as the National Wildlife Federation, should be considered. Support for PARKS International Journal is particularly encouraged as 5000 field managers around the world are reached through this medium. (Priority: Urgent).

In summary, many of the consequences of these and other actions mentioned in Section 8 are self-evident. They will collectively lead to meeting the three objectives of the World Conservation Strategy as well as to increased environmental security and awareness of the objectives outlined by the Global 2000 coalition. In addition to contributing to the social well-being of future generations and the sustainability of life on earth, the consequences of not acting to maintain the diversity of our living resources will be very costly indeed in terms of environmental degradation and in the reduction of the diversity of living resources.

8.2. Action Programmes for Protected Areas in the Tropics

Since 1982 IUCN has developed action plans to provide guidance and assistance to those concerned with improving management effectiveness and in meeting the full range of objectives for which protected areas were established. These action plans have been coordinated by CNPPA within the IUCN Secretariat but involve all parts of the Union -- State Parties, government agencies, and NGOs -- as well as IUCN's major international partners -- UNEP, Unesco, FAO and the WWF. Two further recommendations arise out of this process and are given below.

The first action plan was developed at the World Parks Congress in Bali and has been thus labelled the Bali Action Plan (BAP) (Appendix II). The 10 point action plan is accompanied by a set of 49 activities and a number of specific projects, many of which are now underway. The implementation of the BAP requires the cooperation of all those who prepared it and would ensure that the protected area resources are conserved to form an inseparable part of the modern human heritage.

In addition to general overall and ecosystem level policy activities as outlined in the BAP, another attempt was made to spell out in a detailed fashion for the Indomalayan Realm the actions required to more effectively manage protected areas (and therefore biological diversity). This action plan was developed at a CNPPA working session held in Corbett National Park, India, 4-8 February 1985, by field level managers and key protected area professionals from 12 countries of the realm. The plan is divided into activities to be carried out at the national level and those where international assistance will be required. It outlines both broad geographic priorities and identifies specific sites where conservation action is needed. Finally, it spells out in detail the various inputs required and is attached as Appendix III as an example of what management strategies are required on a realm basis.

The Corbett Action Plan serves to practically demonstrate how concerns for maintaining biological diversity could be applied at the field level in this important realm. Similar action plans have recently been developed for the South Pacific and need to be elaborated and implemented in all other realms. (Priority: High).

Another action plan for one category of protected area - the biosphere reserve - has been developed under Unesco's Man and the Biosphere (MAB) Programme (especially MAB 7 - Islands and MAB 8 - Biosphere Reserves (see Unesco, 1984). As an approved intergovernmental document the plan identifies a range of actions that can develop the multiple functions of biosphere reserves. Along with the cooperating governments, the main entities in actualizing this plan are Unesco, UNEP, FAO and IUCN. As a leader in implementing a national MAB programme the US could play a key role in implementing some of the 35 actions spelled out in the plan. (Priority: Urgent).

The theme of this paper has been that we need to extend and make more secure a worldwide network of parks and reserves to effectively cover all ecosystem types and all essential genetic resources. At the same time, many developing countries need to develop national policies and the requisite management plans and trained manpower needed to translate this network into an effective conservation instrument which brings sustainable benefits to people. Management techniques, although not completely developed are largely available -- what is lacking is the will, the trained manpower and the funds for their application.

While not a panacea, properly managed protected areas provide the best possible protection devices for species and ecosystems which are managed elsewhere in the landscape for direct consumptive purposes. With its manpower and material resources at hand, the US Government, through its various departments and agencies, along with academic institutions, NGOs and private initiatives, could and must play a decisive role in this endeavour.

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BIBLIOGRAPHY

Diamond, J.M. 1975. The island dilemma: lessons of modern biogeographic studies for the design of natural reserves. Biological conservation 7: 129-146.

Diamond, J.M. 1984. Biological Principles Relevant to Protected Area Design in the New Guinea Region. In: McNeely and Miller, Eds. (1984) loc. cit.

Frankel, O.M. and Michael E. Soulé. 1981. Conservation and Evolution. Cambridge University Press, New York. 327 pp.

Harrison, J., K.R. Miller and J.A. McNeely. 1984. The World Coverage of Protected Areas: Development Goals and Environmental Needs. In: McNeely and Miller, Eds. (1984) loc. cit.

IUCN. 1982. IUCN Directory of Neotropical Protected Areas. IUCN, Gland. (Funded by a special grant from the WWF/US).

IUCN, 1984. Categories, Objectives and Criteria for Protected Areas. In: McNeely and Miller, Eds. (1984) loc. cit.

IUCN, 1985. United Nations List of National Parks and Protected Areas. In Press.

IUCN, 1985. Directory of Protected Areas in the Afrotropical Realm. In Press.

MacKinnon, J., G. Child and J. Thorsell, 1986. Protected Areas in the Tropics: A Manager's Handbook. IUCN/UNEP. In Press.

MacKinnon, J. 1985. Outline of Review of the Protected Areas System of the Indomalayan Realm. In J. Thorsell, Ed. Conserving Asia's Natural Heritage. IUCN.

Jorge Padua, M.T., and Angela Tresinari Bernardes Quintao. 1984. A system of national parks and biological reserves in the Brazilian Amazon. In: McNeely and Miller, Eds. (1984) loc. cit.

McNeely, J.A., and K.R. Miller. 1983. IUCN, National Parks and Protected Areas: Priorities for Action. Environ. Conserv. 10(1), Spring. p. 13-21.

McNeely, Jeffrey. 1985. An Expanded Approach to Protected Areas in the Himalaya. Paper presented to workshop on the Management of Protected Areas in the Hindukush-Himalaya. Kathmandu, May 1985.

McNeely,. Jeffrey A., and Kenton R. Miller. 1984. (eds.). National Parks, Conservation and Development: The Role of Protected Areas in Sustaining Society. IUCN/Smithsonian Institution Press, Washington D.C. 825 pp.

McNeely, J.A., K.R. Miller, and J.W. Thorsell. 1985. Objectives, Selection and Management of Protected Areas in Tropical Forests Habitats. In Gartlan, Marsh and Mittermeier, (Eds.). Conservation of Primates in Tropical Forests. In Press.

Miller, K.R. 1978. Planning National Parks For Ecodevelopment. Univ. of Michigan.

Miller, K.R. 1982. Strategy for Training in Natural Resources and Environment - A Proposal for Development of Personnel and Institutions in Latin America and The Caribbean. WWF-US, Washington. 208 pp plus Appendices.

Moore, A.W. 1984. Operations Manual for a Protected Area System. Guidelines for Developing Countries. FAO Conservation Guide 9, FAO, Rome.

Mosha, G.T. and Thorsell, J.W. 1984. Synergism Between Biosphere Reserves and Training Institutions: A Case Study from East Africa. In Conservation, Science and Society. Unesco/UNEP. Paris.

Myers, N. 1979. The Sinking Ark. Pergamon, Oxford.

Natural Resources Defence Council. 1984. Memorandum on US National Park Service and US Fish and Wildlife Service, International Programs.

Panwar, H.S. 1985. Protected Areas and People - The Indian Approach. In Thorsell, J., ed. Conserving Asia's Natural Heritage. IUCN, Gland, Switzerland.

Prescott-Allen, R. 1984. Management of In Situ Genebank. In Proceedings of 24th Working Session of CNPPA, Madrid, Spain.

Prescott-Allen, R. 1985. In Situ Genebanks for Maintenance of Wild Genetic Resources in Tropical Forest Countries. A Pilot Project for Northwest South America. WWF/IUCN Project Report, Gland, Switzerland.

Proud, K.R.S. and J.D. Hutchinson, 1980. Management of Natural Reserves to Maintain Faunal Diversity: A Potential Use for Forest Silviculture. Tropical Ecology and Development 1980: 247-255.

Rijksen, H.D. 1984. Conservation: Not by Skill Alone. The Importance of a Workable Concept in the Conservation of Nature in IUCN. Traditional Life-Styles, Conservation and Rural Development. Commission of Ecology Paper, No. 7.

Salm, R., and J. Clark, 1984. Marine and Coastal Protected Areas: A Guide for Planners and Managers. IUCN, Gland, Switzerland.

Simberoff, D.S. and L.G. Abele, 1976. Island biogeography theory and conservation practice. Science 191, 285-286.

Soulé, Michael E. and Bruce A. Wilcox. 1980. Conservation Biology. Sinauer, Sunderland, Massachusetts. 395 pp.

Thorsell, James. 1982. Evaluating Effective Management in Protected Areas: An Application to Arusha National Park, Tanzania. Paper prepared for World National Parks Congress, Bali, October 1982.

Thorsell, James. 1983. Systems Planning for National Parks and Reserves. Wildlife News, 18(2). African Wildlife Foundation, Nairobi.

Thorsell, James. 1984. A Management Planning Strategy for Khao Yai National Park,. Thailand. Tigerpaper XI(2), FAO, Bangkok.

Unesco, 1984. Action Plan for Biosphere Reserves. Nature and Resources, XX(4), Oct.-Dec.

Wetterberg, G. The Exchange of Wildlands Technology: A Management Agency Perspective. In: McNeely and Miller, eds. (1984) loc. cit.

Wilcox, Bruce A. 1984. In Situ Conservation of Genetic Resources: Determinants of Minimum Area Requirementrs. In: McNeely and Miller, eds. (1984) loc. cit.

World Resources Institute. 1984. Recommendations for a US Strategy to Conserving Biological Diversity in Developing Countries. Washington, 83 pp. plus Appendices.

APPENDICES

I Questionnaire for Evaluating the Effectiveness of Management

II The Bali Action Plan (BAP)

III The Corbett Action Plan

THE ROLE OF PROTECTED AREAS IN MAINTAINING BIOLOGICAL DIVERSITY

WITH SPECIAL REFERENCE TO TROPICAL DEVELOPING COUNTRIES

Paper Prepared for

Food and Renewable Resources Program
Office of Technology Assessment
Congress of the United States

By

James W. Thorsell
Executive Officer
Commission on National Parks and Protected Areas
Gland, Switzerland

International Union for Conservation of Nature and Natural Resources

September 1985

INTERNATIONAL UNION FOR CONSERVATION OF NATURE AND NATURAL RESOURCES

Commission on National Parks and Protected Areas

QUESTIONNAIRE FOR EVALUATING THE EFFECTIVENESS OF MANAGEMENT

Name and designation of area

Evaluator

Date

Regarding:

1. Clearly defined specific objectives to guide management, this area:

a) has written objectives specific to the area.
b) has only broad objectives.
c) lacks specific objectives at present.

2. Legislation, this area:

a) is fully protected by the national or provincial legislation and has a compatible set of regulations specific to the area.
b) is protected by national legislation but does not have a set of regulations specific to the area.
c) is inadequately protected by national legislation and lacks local regulations.
d) is sufficiently protected by national legislation and does not require local regulations.

3. Research, this area at this time:

a) has a strong, well integrated programme of basic and applied research which provides support to the management objectives.
b) has only basic, academic research which provides indirect input to improved management.
c) has *ad hoc* research which may provide support to management objectives.
d) has no research, either basic or applied.
e) has no on-going or planned research programme and local circumstances do not call for one at this time.

4. Basic resources information, this area has the following:

a) inventory of mammals
b) inventory of birds
c) inventory of other vertebrates
d) complete inventory of plants
e) partial inventory of plants
f) vegetation map
g) inventory of invertebrates
h) geological map
i) soil map
j) climatic data
k) hydrological data
l) topographic map
m) aerial photographs
n) research station

5. Basic ecological information, this area has the following:

a) studies of wildlife population dynamics
b) studies of population status and trends of endangered species
c) information on relationships between wildlife and the habitat
d) studies of predator-prey relationships
e) information on the carrying capacity of the habitat for key species of large mammals
f) information on disease reservoirs among the wildlife studies of vegetation succession

6. Watershed management, this area, (check more than one if necessary):

a) protects a watershed or watersheds considered to contribute to the welfare of downstream human populations (e.g. drinking water, irrigation, flood control).
b) protects a watershed or watersheds considered to contribute to downstream ecological process (e.g. estuarine and coastal fisheries).
c) because of its importance to human welfare, is left unmanipulated (in a natural state).
d) is lightly manipulated, through natural means (e.g. fire control, reforestation).
e) is manipulated through engineering works (checkdams, streams channelization, terracing).

7. Genetic resources, this area:

a) has a number of species of plants/animals of potential or actual benefit to humanity and these receive special attention in management decisions.
b) probably has a number of species of plants/animals of potential or actual benefti to humanity, but there is little available data about them so they receive little special attention.
c) has little data available but genetic resources are still given special consideration in management decisions.
d) has management decisions based on overall intrinsic values of nature so genetic resources are not given specific attention.

8. Management plan, this area:

a) has an approved and current management plan which is being implemented.
b) has a management plan but it has not been accepted/approved/implemented.
c) management plan is being prepared.
d) lacks a management plan at present.
e) lacks a management plan and local circumstances do not call for one at this time.

9. Zoning, this area:

a) has a zoning plan which effectively controls human impact and development relative to carrying capacity.
b) has a zoning plan which partially controls human impact and development relative to carrying capacity.
c) does not yet have a zoning plan, but such a plan is being prepared.
d) does not have zoning plan.
e) does not have zoning plan, nor is a plan required at present.

10. Boundaries, this area:

a) has physically and narratively demarcated boundaries which effectively define the area.
b) has demarcated boundaries in certain key areas and this is felt adequate.
c) has some boundaries demarcated, but these are felt insufficient.
d) lacks demarcation of boundaries.
e) lacks or partially lacks formal demarcation of boundaries but this is deemed appropriate for the current situation.

11. Ecologically sufficient boundaries, this area:

a) encloses an entire ecosystem, so is fully self-sufficient.
b) comprises the upper part of a watershed, but has no control over the lower parts.

c) comprises the lower part of a watershed, but has no control over the upper parts.
d) comprises only a fragment of a total ecosystem, requiring intensive management to maintain natural functioning.

12. Protection of natural resources, this area:

a) is fully and effectively protected from resource exploitation.
b) is protected at a level appropriate to area objectives.
c) is used only by local people for their own needs.
d) suffers from illegal harvesting of vegetation, illegal grazing, or poaching of animals.
e) exploitation of resources is legal.

13. Formal education, this area:

a) has adequate educational facilities and is well used by local/national educational institutions.
b) is used by local/national educational institutions for planned, supervised field trips but htere are few local facilities.
c) is used by students for informal, unsupervised field trips.
d) is seldom used for educational purposes.

14. Informal education, this area has the following visitor facilities:

a) Leaflets
b) Maps
c) Marked trails
d) Signs
e) Guide service
f) Information centre
g) Audio-visual programmes
h) Public transportation
i) Hides

15. Tourism, this area:

a) is important for tourism and has all necessary facilities for present levels of visitor use.
b) receives so many tourists that the reserve staff has little time for other management activities.
c) receives many tourists, but facilities are inadequate.
d) is of only minor importance for tourism at present.
e) does not include tourism as an objective.

16. Political support (check more than one if necessary):

a) the central government has made a commitment to attain the conservation objectives of the area.
b) the regional government has made a commitment to attain the conservation objectives of the area.
c) the local people are in support of the area.
d) lack of political support is a major problem.
e) insufficient support (or active opposition) by local people is a major problem.

17. Local participation, this area:

a) has a local advisory committee or otherwise involves local people in decision-making.
b) involves at least some officials of local government.
c) involves local people only informally.
d) does not involve local people at all.

18. Benefits to local people, this area:

a) brings real benefits to the local people in terms of watershed protection, employment opportunities, buffer zone development, economic subsidy, or other related developments.
b) brings some benefits to the local people.
c) brings virtually no benefits to the local people.

19. Budget, this area:

a) has sufficient budget to attain its objectives as stated in management plan.
b) receives a budget which is insufficient to allow management plan to be fully implemented.
c) receives a budget which allows only basic maintenance and staffing.
d) lacks a budget.

20. Maintenance, this area:

a) has a budget for maintenance and this is sufficient to keep equipment/facilities in reasonable working order.
b) had a budget for maintenance but this is insufficient to keep equipment/facilities in reasonable working order.
c) does not have any budget for maintenance but maintenance of equipment/facilities is still acceptable.
d) has no budget for maintenance and equipment/facilities suffering as a result.

21. Personnel, this area:

a) has sufficient personnel to attain the specified management objectives.
b) lacks sufficient personnel at present.
c) has no personnel at all.

22. Equipment, this area:

a) is sufficiently well equiped to attain its management objectives.
b) needs more vehicles/boats.
c) needs more uniforms/equipment for rangers.
d) needs more housing/guard-posts/headquarters buildings.
e) needs more survey equipment
f) needs more medical/first aid equipment.
g) needs more communication equipment.
h) needs more office equipment.

23. Role of external support, this area (check more than one if necessary):

a) is sufficiently well managed and funded that no outside support has been requested.
b) has received/is receiving external support.
c) receives additional support from within the country.
d) needs outside support, which is being sought.
e) needs outside support but such support is not being sought.

THE BALI ACTION PLAN:

The Steps Necessary to Enable Protected Areas to Meet the Needs of the 1980s

By

IUCN's Commission on National Parks and Protected Areas

1. INTRODUCTION

The World National Parks Congress met in Bali, Indonesia, from 11 to 22 October, 1982, with the primary objective to define the role of national parks and other protected areas in the process of social and economic development. To establish priorities for the coming critical years, the Congess prepared a series of 20 Recommendations; these have now been published by IUCN and widely distributed. In addition, working groups from the world's eight biogeographic realms presented reports at Bali on priorities for each realm and many of the case studies and other presentations provided examples which should be emulated; the "Future Directions" addresses from each realm were particularly pertinent in providing thoughtful analyses of future trends. Based on this material, the major points of an Action Plan were presented to the closing session of the Congress. Further work on the plan was done at the IUCN secretariat, resulting in the Bali Action Plan.

The Bali Action Plan recognizes that there are already competent government agencies in most countries whose responsibility is the management of national parks and other sorts of protected areas, and that each of these agencies is already carrying out a programme of work relevant to the needs and priorities of the country involved; the total budgets of these agencies exceeds $2 thousand million. However, the 450 professionals attending the Congress also recognized that there was a serious lack of understanding of management tools (biogeography, zoning, monitoring, training procedures, protected area economics, etc.), that budgets are not always allocated to the most important priorities, that clear objectives exist for relatively few protected areas, that management plans are the exception rather than the rule, that relevant information is not flowing as well as it should, that training is lagging far behind needs, and that government officials and the public generally undervalue the role of protected areas in environmentally-sound development.

The Bali Action Plan aims to provide guidance and assistance to those national agencies which are interested in improving their own management effectiveness in meeting the objectives for which their protected areas were established. The Bali Action Plan has ten Objectives. Under each objective is a series of Activities which is not exhaustive but does indicate the sorts of activities which will be necessary for the objective to be obtained.

Many of the government agencies charged with the responsibility for managing protected areas are carrying out projects or programmes which could make major contributions to the Bali Action Plan, and provide significant guidance to other agencies facing similar problems.

Objective 1. TO ESTABLISH BY 1992 A WORLDWIDE NETWORK OF NATIONAL PARKS AND PROTECTED AREAS, TO COVER ALL TERRESTRIAL ECOLOGICAL REGIONS.

Activity 1.1 Develop and make available to all responsible for protected areas, tools and guidelines for the identification and selection of natural areas critical for meeting the objectives of conservation and for supporting development.

Activity 1.2 Promote necessary technical, scientific and financial support for the identification, selection, planning and management of protected areas which fit strategically into the world network.

Activity 1.3 Further develop and distribute a biogeographical classification system for use in the global analysis of protected area coverage.

Activity 1.4 Develop and distribute a more detailed biogeographical classification system with a flexibility of scale which can be used in the analysis of protected area coverage at a variety of regional and national levels.

Activity 1.5 Promote the detailed evaluation at the regional and country level of protected area coverage.

Objective 2. TO INCORPORATE MARINE, COASTAL AND FRESHWATER PROTECTED AREAS INTO THE WORLDWIDE NETWORK.

Activity 2.1 Develop and distribute concepts and tools for the establishment of protected areas in marine, coastal and freshwater environments.

Activity 2.2 Develop a classification system for categories of marine, coastal and freshwater protected areas.

Activity 2.3 Further develop and distribute biogeographical classification systems for marine, coastal and freshwater protected areas, at both the global level and at the regional/national level.

Activity 2.4 Incorporate scientists, managers, administrators and supporters of marine, coastal and freshwater conservation into the protected areas community.

Activity 2.5 Promote the establishment of marine, coastal and freshwater protected areas by all states, including the extension of all currently protected littoral areas into the aquatic environment.

Activity 2.6 Promote cooperation between neighbouring nations sharing resident and migratory species to establish networks of protected areas and other regulations to meet the critical needs of those species, with special priority for threatened and endangered species.

Objective 3. TO IMPROVE THE ECOLOGICAL AND MANAGERIAL QUALITY OF EXISTING PROTECTED AREAS.

Activity 3.1 Develop and make available tools and guidelines for the evaluation of the ecological capacity of protected areas to maintain living resources, and the evaluation of area management to ensure that appropriate measures are being applied.

Activity 3.2 Promote the development of concepts and methods which will lead to scientific principles for management and support the continuous analysis of conservation requirements for each area.

Activity 3.3 Document the living resources contained in protected areas, including preparing and disseminating inventories of wild species and populations of known or likely value as genetic resources.

Activity 3.4 Develop and implement a system of reporting on protected areas under particular threat.

Activity 3.5 Support a systematic approach to the preparation of area and system management plans which provide for management and development to be in accordance with an appropriate range of conservation objectives.

Activity 3.6 Reinforce measures to reduce the external threats to protected areas.

Objective 4. TO DEVELOP THE FULL RANGE OF WILDLAND MANAGEMENT CATEGORIES.

Activity 4.1 Develop and make available the concepts and tools necessary for the design and implementation of each category, in both terrestrial and aquatic habitats.

Activity 4.2 Establish pilot protected areas for each category, within each realm, to demonstrate to political leaders and local peoples the importance of these alternatives for supporting social and economic development through sustainable approaches to resource management.

Activity 4.3 Include all 10 wildland management categories on the United Nations List of National Parks and Protected Areas.

Activity 4.4 Provide for the establishment of *in situ* gene banks.

bjective 5. TO PROMOTE THE LINKAGE BETWEEN PROTECTED AREA MANAGEMENT AND SUSTAINABLE DEVELOPMENT.

Activity 5.1 Develop and make available the tools for the survey of ecological processes, habitat requirements, and other components of protected area integrity to enable managers to critically examine the context for area conservation, and be able to associate conservation with development in adjacent lands.

Activity 5.2 Work with governments and development assistance agencies to achieve the incorporation of protected area considerations and support within development projects.

Activity 5.3 Develop policy guidelines and legal instruments regarding the use of protected areas for research, environmental monitoring and the collection of scientific materials.

Activity 5.4 Develop tools and guidelines for the practical incorporation of new objectives for protected area management of particular relevance to sustainable development, including environmental monitoring and genetic resources conservation.

Activity 5.5 Investigate and utilize the traditional wisdom of communities affected by conservation measures, including implementation of joint management arrangements between protected area authorities and societies which have traditionally managed resources.

Activity 5.6 Carry out research to determine ways to foster appropriate recreation and tourism in protected areas for which tourism has been deemed an objective, and to minimize the adverse impacts of such activities.

Activity 5.7 Develop ways and means of promoting greater public support for protected areas.

Objective 6. TO DEVELOP THE HUMAN CAPACITY TO MANAGE PROTECTED AREAS, ESPECIALLY THROUGH TRAINING.

Activity 6.1 Promote the establishment and recognition of protected area management as a professional career of vital relevance to society.

Activity 6.2 Develop and promote training seminars, courses and workshops at the regional and local levels for protected area managers.

Activity 6.3 Strengthen support to regional and national training schools.

Activity 6.4 Promote the establishment of local, in-service training efforts for all personnel.

Objective 7. TO DEVELOP ECONOMIC TOOLS FOR SUPPORTING PROTECTED AREAS.

Activity 7.1 Develop and distribute tools for the analysis of values, tangible and non-tangible, monetary and non-monetary, associated with protected natural areas.

Activity 7.2 Promote the quantification of values which relate conservation to development, specifically watershed protection but also including genetic resources, pollution control, soil formation, amelioration of climate, provision of recreation and tourism, and others of nature's services.

Activity 7.3 Explore and publish concepts and tools which relate ecology and economics to promote a more consistent perspective for analyzing and explaining the role of protected areas in sustaining development.

Objective 8. TO IMPLEMENT AN EFFECTIVE INVENTORY AND MONITORING SERVICE.

Activity 8.1 Expand and develop the Protected Areas Data Unit (PADU) and related components of the IUCN Conservation Monitoring Center(CMC), to provide information on protected areas, guide the determination of priorities, and support development agencies (both national and international) in relating the design of development projects to critical protected areas.

Activity 8.2 Publish and distribute Realm-based directories and periodic reports to inform and support national and international organizations in their planning activities.

Activity 8.3 Promote arrangements by international organizations, governments, and regional associations of nations for the long-term development and use of data collection systems, such as satellite remote sensing, covering all protected areas.

Activity 8.4. Promote and implement methodology for implementing monitoring systems.

Objective 9. TO IMPLEMENT INTERNATIONAL COOPERATION MECHANISMS.

Activity 9.1 Integrate and strengthen ties between protected areas management and the Man and the Biosphere Programme, the Global Environmental Monitoring System, and the World Heritage Convention, to realize the full potential of these instruments for the common objectives of conservation and sustainable development.

Activity 9.2 Encourage and advise all States on the preparation, use, and, where required, updating of international legal instruments which support protected areas.

Activity 9.3 Explore and promote the development of tools and mechanisms for the fair sharing of costs and benefits associated with protected areas management, both among nations and between protected areas and adjacent communities.

Activity 9.4 Explore the potential for new agreements and instruments needed to further strengthen international cooperation, particularly in relationship to genetic resources.

Objective 10. TO DEVELOP AND IMPLEMENT A GLOBAL PROGRAMME TO SUPPORT PROTECTED AREA MANAGEMENT.

Activity 10.1 Design and implement regional action programmes to ensure practical accomplishments close to the ground, taking into account relevant cultural and institutional diversity, and the necessary responsiveness to local needs.

Activity 10.2 Provide technical and scientific guidance through the publication of a series of documents on practical subjects of global concern to protected area management such as those noted in the preceding items.

Activity 10.3 Establish a communications network with the global community responsible for or supporting protected areas to ensure the flow of information and support the identity of the protected area profession.

Activity 10.4 Build the institutional support necessary to carry out these activities as follow up from the Congress.

Activity 10.5 Initiate steps for the celebration of the next World Congress on National Parks in 1992, with intermediate international, regional and national events designed to further the Bali Action Plan.

Activity 10.6 Charge the IUCN to monitor the implementation of this Plan and to report on progress at the next Congress.

THE CORBETT ACTION PLAN

Goal 1 THE ESTABLISHMENT OF A REPRESENTATIVE NETWORK OF PROTECTED AREAS WITHIN THE INDOMALAYAN REALM

Objective 1.1. TO USE MODERN BIOGEOGRAPHIC CONCEPTS TO PREPARE REVIEWS OF NATURAL HABITATS AND ECOLOGICAL COMMUNITIES WITHIN EACH NATION AND DETERMINE THE ADEQUACY OF PROTECTED AREA COVERAGE OF THESE HABITATS AND COMMUNITIES.

Activities at the National Level:

1.1.1. Using the currently accepted biogeographic zonation for the country, map the major habitats and their faunal communities, including the locations of centres of endemism, pristine habitats, and areas of exceptional species and community diversity.

1.1.2. Prepare inventories of key species in each biogeographic unit and in each protected area.

1.1.3. Determine whether the habitats and fauna in the country, especially centres of endemism and areas of high diversity, have adequate and viable conservation status, and identify the gaps in the national reserve system.

1.1.4. Determine whether existing protected areas are of large enough size and are receiving appropriate management to fulfil their protective role.

1.1.5. Determine where additional protected areas are required and take steps to establish such areas; and identify areas where conservation measures need to be implemented or strengthened.

Activities at the International Level:

1.1.6. Conduct, prepare, and disseminate widely a protected area systems review for the Indomalayan Realm, linking the distribution of habitats and species, in order to provide a framework for national action. (In preparation by IUCN, to be completed by mid-1986).

1.1.7. Provide a realm-based data base on protected areas to compile the information collected by governments and other experts; and publish relevant data as a Directory of Indomalayan Protected Areas. (In preparation by IUCN, to be completed by mid-1986).

1.1.8. Provide the necessary information and other forms of support to governments to enable them to assess the adequacy of their protected area coverage. (Action by IUCN, WWF, Unesco, FAO, others).

1.1.9. Promote action by governments as a follow-up to the systems review and Realm directory. (Action by IUCN, WWF, ASEAN, UNEP).

1.1.10. Promote collaboration by governments in developing a biogeographical classification system which could be used throughout the Realm, at a scale which would be meaningful for assessing national coverage and protecting biological diversity. (Action by IUCN).

Objective 1.2. TO ENSURE ADEQUATE CONSERVATION STATUS FOR PRIORITY BIOLOGICAL COMMUNITIES.

Activities at the National Level:

1.2.1. From objective 1.1 above, give priority for on-the-ground action to biomes, habitats, and areas considered fragile and threatened so that suitable areas can be protected. Examples of areas which require urgent attention include:

- St. Martin's Island of Bangladesh (as a marine national park);
- Kyatthin Wildlife Sanctuary in Burma (needs to be up-graded to Nature Reserve and provided with professional staff);
- Thamihla Kyun and South Moscos, and Kadonly Kyun in Burma (need to be established as marine reserves);
- The Batu Apoi Forest Reserve of Brunei (should be upgraded to national park status);
- Mishmi Hills (especially areas of takin habitat);
- Distinctive communities of Andaman (especially the virgin forests of the middle Andamans), Nicobar, and Lakshwadeep islands, especially those areas with freshwater lakes;
- A sanctuary for the Indian Bustard in Andhra Pradesh;
- The unique ecosystem of Simlipal Tiger Reserve in Orissa;
- Indravati National Park, Bastar, Madhya Pradesh;
- The bamboo forests of Saranda, Bihar;
- Krusadei and Shingle islands of the Rameshwaram coast (India);
- Logtak Lake in Manipur, India;
- A marine park in the Gulf of Mannar, India;
- Neora Valley of West Bengal (as a national park);
- Higher altitude montane forest areas in west, central and east Himalayas, including the Inner Seraj Pandra, areas of Outer Seraj and Bushahar, and Bharmour area of Chamba in Himachal Pradesh;
- Cold deserts of Ladakh, Lahul and Spiti in north India;
- Moist tropical forests of northeast India (Arunachal Pradesh, Assam, Meghalaya);
- Semi-arid and temperate grasslands in northwest India;
- Khadir Island and adjacent areas of the Great Rann of Kutch (India);
- Lower-level moist forest of the Western Ghats, India;

- Tropical lowland forests of Kalimantan, Indonesia (including appropriate action on Peraira S. Mahakam, Danau Semagang, Berambai, Kelompok Hutan Kapur, Muara Sebuku, Sungai Kayan-S. Mentarang, Pleihari Martapura, Muara Uya, Hutan Sambas, Gn. Niut/Becapa, and Danau Sentarum);
- Surveys of priority areas of Sumatra, including Tiga Puluh Mountains, Kota Panjang, Torgamba, and Bukit Patah;
- Mangrove forests in Java (Indonesia);
- Coastal and marine habitats in Indonesia, following recommendations made in the Master Plan for Coastal and Marine Protected Areas;
- Improved management of Koulen-Promtep, Lomphan and Phnom Prich Reserves in Kampuchea;
- Establishment of suitable area for conservation of kouprey in Champassak (Kampuchea)(an area of 160,000 ha in Muong Moun Lapamok District has been proposed);
- Endau Rompin National Park (Malaysia);
- Establishment of reserve on Kalumpang Island, Perak (Malaysia);
- Limestone forests and heath forests in Sarawak and Sabah (Malaysia)(threatened by logging/expansion of plantation crop areas);
- Lowland peat swamp and mangrove forests in Sarawak;
- The Silabukan-Lumerau Forest Reserves block in Sabah;
- Improved management of the Tabin Wildlife Sanctuary in Sabah;
- Evaluation of Koshi Tappu Wildlife Reserve (Nepal) for its appropriateness to conserve wild water buffalo;
- Mt. Pulong, Luzon as a national park (Philippines);
- Honda Bay, Palawan as a marine park (Philippines);
- Tubataha Reef and San Miguel Island, Palawan (Philippines);
- Apo Reef, Mindoro (Philippines);
- Improved protection of tamaraw habitat in Iglit/Baco National Park (Philippines);
- The waters adjacent to Wilpattu National Park (Sri Lanka)(to be declared national park);
- Knuckles Range (Sri Lanka)(to be declared Strict Nature Reserve);
- Beung Boraphet and Songkhla Lake (Thailand);
- Mangrove forests in Minh Hai (Vietnam);
- Nam Baicattien (Vietnam)(as a national park);
- Tropical forests in High Plateau Tay Nguyen (Vietnam).

1.2.2. Provide particular attention to protecting coastal and marine habitats, including identifying important areas, developing the administrative structures to manage them, and devising appropriate management methodologies for these highly productive areas.

1.2.3. Ensure that delegations to meetings of UNEP Regional Seas Programmes are fully briefed on the role of coastal and marine protected areas, and are prepared to support action in this field.

Activities at the International Level:

1.2.4. Make available to national conservation agencies any concepts, information, and expertise required to provide enhanced protection to key habitats, including islands, coastal and marine habitats, wetlands, and mountains. (Action by IUCN, WWF, Unesco, UNEP.)

1.2.5. Provide particular support to the marine conservation needs of the Maldives and Chagos archipelagos.

1.2.6. Assemble data on important wetlands in the Indomalayan Realm, to be used to identify key areas for protection. (Action by IUCN, to be completed by end 1986.)

1.2.7. Provide a framework for international action on island, coastal and marine protected areas through the UNEP Regional Seas Programme (South Asian and East Asian regional seas.)

Objective 1.3. TO ENSURE THAT RELEVANT CATEGORIES OF PROTECTED AREAS ARE GIVEN LEGAL PROTECTION AT AN APPROPRIATE LEGISLATIVE LEVEL.

Activities at the National Level:

1.3.1. Examine national legislation to see if the relevant IUCN Management Categories are mentioned and receive appropriate legal recognition.

1.3.2. Give priority to setting up a network of strictly protected areas (Category I - Strict Nature Reserves) within each major habitat or biotic community, possibly based on zones within existing reserves.

1.3.3. Examine the management status and objectives of existing parks, sanctuaries and other reserves to see if their designated category is providing the appropriate level of protection.

1.3.4. The Governments of Bhutan, Brunei, Burma, China, Indonesia, Laos, Malaysia, Maldives, Philippines, Singapore, Thailand, and Vietnam should consider acceding to the World Heritage Convention and its implementation in their country.

1.3.5. Each relevant government agency should select outstanding areas of biological and natural value for nomination to the World Heritage List, taking into account the possibilities for trans-frontier sites.

1.3.6. Provide necessary support for Man and the Biosphere (MAB) activities, particularly by forming or activating MAB National Committees, implementing the Biosphere Reserve Action Plan, and establishing Biosphere Reserves which may be included in the international network.

Activities at the International Level:

1.3.7. Provide advice to governments on request on legislation, regulations, and other administrative measures to establish the full range of categories of protected areas, including biosphere reserves. (Action by IUCN's Environmental Law Centre and Commission on Environmental Policy, Law, and Administration.)

1.3.8. Provide a framework for international cooperation through the World Heritage Convention and the Biosphere Reserve programme, and provide relevant support to governments for preparing indicative inventories and strengthening field action in World Heritage properties and Biosphere Reserves. (Action by Unesco, with support from IUCN.)

1.3.9. Assist in the preparation of projects for submission to the World Heritage Committee for funding. (Action by Unesco, CNPPA.)

Goal 2 THE DEVELOPMENT OF MANAGEMENT CAPABILITY FOR PROTECTED AREAS

Objective 2.1. TO ENSURE THAT EACH NATION HAS STRONG AND EFFECTIVE WILDLIFE CONSERVATION AUTHORITIES AT THE CENTRAL AND STATE OR PROVINCIAL LEVELS SO THAT THE NETWORK OF CONSERVATION AREAS CAN BE ADEQUATELY MANAGED.

Activities at the National Level:

2.1.1. Develop a strong central authority for conservation/wildlife management at both the administrative and technical levels, including specialist technical officers dealing with management planning, field staff supervision, training, research and monitoring, education/interpretation, wildlife health, and captive breeding and zoos, to ensure adequate inputs at state and field levels.

2.1.2. Develop fully independent wildlife/conservation departments with appropriate internal career structures.

2.1.3. Recruit dedicated and highly motivated staff at all professional levels within these departments, and provide opportunities for advancement within the system.

Activities at the International Level:

2.1.4. Provide support to training efforts, through workshops, fellowships, curriculum development, training manuals, and other means. (Action by FAO, Unesco, WWF, IUCN.)

2.1.5. Ensure attendance at the International Seminar on National Parks Management by senior park staff from the Realm. (Action by WWF, Unesco, IUCN, FAO.)

2.1.6. Provide support to assessments of regional training needs and manpower planning. (Action by FAO.)

Objective 2.2. TO DEVELOP TRAINING FACILITIES SUFFICIENT TO MEET MANPOWER NEEDS.

Activities at the National Level:

2.2.1. Designate a specialized national or regional training institution for senior and middle professional level protected area staff.

2.2.2. Encourage and promote the teaching of wildlife management at university or other appropriate level.

2.2.3. Develop suitable in-service training programmes with an emphasis on practical field techniques for field and technical staff.

Activities at the International Level:

2.2.4. Sponsor workshops on management planning, including the demonstration of management planning methodology based on the Khao Yai National Park (Thailand) experience as a model. (Action by IUCN, WWF.) Priority areas include:

- Western Himalayan fauna and flora in Sainj-Seraj area of Kullu;
- Sinharaja Forest Reserve, Sri Lanka (in progress for mid-1985, funded by WWF-IUCN);
- Tien Teo Reserve, Vietnam;
- Workshops on management of wetlands, islands, and coastal and marine protected areas.

Objective 2.3. TO DEVELOP SOUND MANAGEMENT POLICIES AND OBJECTIVES FOR PROTECTED AREAS AND TO ENSURE THAT ADEQUATE MANAGEMENT PLANS ARE PREPARED FOR EACH AREA.

Activities at the National Level:

2.3.1. Document the values and objectives of each protected area so as to specify clearly the purpose of its protection status.

2.3.2. Draw up management plans to protect and perpetuate these specific values.

2.3.3. Formulate specific management policies for buffer areas surrounding the protected areas, and for adjacent lands not receiving buffer zone status.

2.3.4. Introduce the necessary enabling legislation, if it is not already in existence; or revise existing legislation as required.

2.3.5. Develop special programmes for managing livestock around protected areas.

Activities at the International Level:

2.3.6. Identify a few protected areas in each country (biogeographic unit) representing a range of management categories as "Demonstration Protected Areas", where special support will be sought for equipment, management, education, training, etc. Possibilities include:

- Game Reserve (Elephant) in Teknaf Region of Cox's Bazar Forests (Bangladesh)
- Sundarbans of Bangladesh
- Manas Wildlife Sanctuary (India, Bhutan)
- Dudhwa National Park (India)
- Gir National Park (India)
- Keibul Lamjao National Park (India)
- Silent Valley National Park (India)
- Desert National Park (India)
- Tirthan Sanctuary in Himachal Pradesh (India)
- Kerinci-Seblat National Park (Indonesia)
- Ujung Kulon National Park (Indonesia)
- Komodo National Park (Indonesia)
- Dumoga-Bone National Park (Indonesia)
- Angkor Wat (Kampuchea)
- Danum Valley (Sabah, Malaysia)
- Gunung Mulu (Sarawak, Malaysia)
- Kirthar National Park (Pakistan)
- Mt. Apo (Philippines)
- Mt. Iglit-Mt. Baco National Park (Philippines)
- Protected areas in Mahaweli (Sri Lanka)
- Sinharaja Forest Reserve (Sri Lanka)
- Huay Kha Khaeng-Thung Yai complex (Thailand)
- Ba Be (Vietnam)
- Cat Ba and Halon Bay (Vietnam)
- Tien Tao (Vietnam)

Objective 2.4. TO PROVIDE EACH MANAGEMENT UNIT WITH SUFFICIENT RESOURCES TO IMPLEMENT MANAGEMENT ACTIVITY IN THE FACE OF INCREASING THREAT TO THESE AREAS.

Activities at the National Level:

2.4.1. Provide necessary documentation to persuade planning and finance ministries that conservation areas need adequate staff, funds, equipment and other resources for their long term survival, and to ensure that they are contributing to rural development in appropriate ways.

2.4.2. Provide specialized resources - vehicles, boats, radios, aircraft usage, equipment, staff - as necessary.

2.4.3. Develop specialized teams in such areas for anti-poaching, dealing with wildlife problems, planning, and interpretation at the appropriate local level to assist the limited resources of individual areas.

Activities at the International Level:

2.4.4. Promote appropriate means of dissemination of research findings from protected areas in the Indomalayan Realm, including investigating the need for a specialized journal on the subject.

2.4.5. Organize workshops on research priorities, planning, and research methodology appropriate to the Indomalayan Realm.

2.4.6. Compile and maintain a list of protected areas under special threat. (Action by IUCN.)

Objective 2.5. TO DEVELOP THE CAPABILITY TO CARRY OUT RESEARCH AND MONITORING ACTIVITIES IN PROTECTED AREAS, AND TO APPLY THE RESULTS TO IMPROVING MANAGEMENT.

Activities at the National Level:

2.5.1. Create a specialized research coordination post at the central level to actively promote much greater research involvement and the provision of adequate funds for research promotion; or develop other means of promoting research, such as publishing an official "List of Research Priorities in Protected Areas" for the country.

2.5.2. Develop strong field-oriented research centres in the ecological and socio-economic sciences, possibly in collaboration with universities, research institutes, etc.

2.5.3. Develop appropriate research and monitoring capability directly related to management needs within each major protected area or group of areas, including adequate staff, equipment, funding, career advancement, etc.

2.5.4. Ensure that relevant research results are employed in the development of improved management procedures.

Goal 3 DEVELOPMENT OF NATIONAL CONSERVATION POLICIES WHICH ARE SOCIALLY ACCEPTABLE AND INTEGRATED INTO NATIONAL DEVELOPMENT AS A WHOLE

Objective 3.1. TO PROMOTE WILDLIFE CONSERVATION WITHIN THE FRAMEWORK OF ALL NATURAL RESOURCE CONSERVATION (SOIL, AIR, WATER AND BIOLOGICAL VALUES) AT THE NATIONAL AND LOCAL LEVELS AND TO PROMOTE THE CONCEPT OF CONSERVATION AND DEVELOPMENT AS LAID DOWN BY THE WORLD CONSERVATION STRATEGY.

Activities at the National Level:

3.1.1. Help fomulate and implement a national conservation strategy covering all natural living resources.

3.1.2. Promote the concepts and values of conservation at all possible national fora and levels, including increased use of the news media and educational facilities.

3.1.3. Organize seminars and workshops for administrators and decision makers in which World Conservation Strategy concepts are discussed and action agreed for their implementation.

Action at the International Level:

3.1.4. Document cases where effective management of protected areas has led to tangible benefits for local people and the nation, and disseminate this documentation widely. Examples include:

- Improved natural product (honey and fish) availability after protection and man-eating by tigers reduced in the Sundarbans (India and Bangladesh);
- Lessening of seasonal damage to crops outside the boundry of Dudhwa National Park (India) following erection of anti-deer electric fence along portion of park boundary;
- Improved quality of life for peripheral villages at Gir National Park in Gujarat (India);
- Environmental awareness enhanced at Hingolgarh Nature Education Sanctuary in Gujarat (India);
- Improved dry season stream flow from Kanha and Palamau National Parks (India);
- Indonesian nature reserves (Bantumurung, Sulawesi; Mirapura, Sumatra; Gunung Jagat, Java) as sources of germplasm for national crop improvement programmes;
- Irrigation and protected areas in Dumoga-Bone National Park, Indonesia;
- Tourism development in Komodo National Park, Indonesia;
- Public education at Sepilok Forest Reserve, Sabah;
- Sarawak Forest Dept/WWF-Malaysia study on dependence of local people on forest produce, with implications of conservation management of hunted wildlife for the long-term benefit of the local people;
- Tourism development and conservation awareness at Turtle Islands, Sabah;
- Turtle management in Pakistan;
- Marine resources replenishment in the Philippines;
- Protected areas and dams in the Mahaweli region of Sri Lanka;
- Trekking programme and community development in Khao Yai region, Thailand;
- Protected mangrove forest in Vietnam.

3.1.5. Provide expertise and support to NCS activities in Malaysia, Nepal, Pakistan, Philippines, Sri Lanka, and Vietnam, and ensure that protected area elements are fully included in the strategies (action by IUCN and development agencies).

3.1.6. Provide international support for national awareness activities, particularly:

- Support to WWF (India) ongoing awareness activities, including nature clubs, nature camps, National Council for Education, Research, and Training (NCERT);
- Preparation of audio-visual packages suitable for decision makers, and for others at different levels (visuals with scripts in local languages which can be communicated by the equipment operators in the local language will be required);
- Provision of sturdy projecting equipment and means of transportation;
- Training of qualified and motivated personnel, particularly operators, to conduct A/V programmes, primarily in rural areas, and in urban areas;
- Supporting the provision of relevant video material from BBC, Survival Anglia, etc. to the Indomalayan Realm, including making scripts available in the local languages.

3.1.7. Support the efforts of the Government of China to prepare a regional land-use management scheme, including a series of protected areas, for the Xishuang Banna area of Yunnan (action: IUCN).

Objective 3.2. TO RECOGNIZE POPULATION GROWTH AND INCREASED PRESSURE ON LAND AS MAJOR FACTORS AFFECTING CONSERVATION AND TO SUPPORT NATIONAL POLICIES AIMED AT REGULATING THESE FACTORS.

Activities at the National Level:

3.2.1. Support national population policies by providing data, case histories and ecological arguments to promote population stability and wise land use.

3.2.2. Assist government agencies in the planning of areas to accept the new population increases in less environmentally critical areas.

3.2.3. Develop sound and convincing arguments which demonstrate that protecting critical natural areas helps support food production outside these areas, through watershed protection, soil formation, micro-climate amelioration, genetic resources, meat production on marginal lands, etc.

3.2.4. Develop special training courses on conservation for social workers who deal directly with human welfare, particularly around protected areas.

Activities at the International Level:

3.2.5. Maintain a continuous level of support for informed population policies in fora, publications, and discussions dealing with natural resource conservation. (Action by all international agencies);

3.2.6. Maintain financial support for international organizations dealing with population issues, such as IPPF, Unicef, World Population Council, etc. (Action by all international agencies and donor governments);

3.2.7. Promote applied research into human ecology in areas of importance for conservation, including such areas as:

- the Himalayas adjacent to protected areas in Himachal Pradesh and Uttar Pradesh, India;
- Keibul Lamjao (India);
- Abuhujmar (India);
- transmigrant populations adjacent to protected areas in Indonesia;
- Shifting cultivators adjacent to Kinabalu National Park, Sabah;
- Mt. Apo region of the Philippines;
- areas surrounding the national parks and proposed national parks in the Maduru Oya basin, Sri Lanka;
- the area surrounding Khao Yai National Park in Thailand;
- Cuc Phuong National Park (Vietnam).

Objective 3.3. TO MAKE SUITABLE PARTS OF THE PROTECTED AREAS SYSTEM AVAILABLE TO THE PUBLIC FOR RECREATION AND EDUCATIONAL USES.

Activities at the National Level:

3.3.1. Examine the protected areas system and select areas suitable for development as tourist and recreation zones.

3.3.2. Develop these zones in an aesthetic manner so as to promote visitors' understanding and enjoyment of nature.

3.3.3. Provide relevant educational and interpretation facilities in these zones.

Activities at the International Level:

3.3.4. Support government agencies in their efforts to design, promote, and implement a few demonstration projects on making protected areas accessible for local recreation, including such areas as:

- Bhawal National Park (Bangladesh)
- Himchari National Park, Cox's Bazar (Bangladesh)
- Madhupur National Park (Bangladesh)
- Keoladeo Ghana National Park (Bharatpur, India)
- Corbett National Park (India)
- Kanawar Sanctuary in Parvati Valley (Himachal Pradesh, India)
- Periyar, Van Vihar Bhopal, Shivpuri, and Panna national parks (India)
- Bali Barat National Park (Indonesia)
- Gunung Halimun Nature Reserve (Indonesia)
- Batan Ai (proposed) National Park (Malaysia) for recreational development
- Kinabalu National Park (Sabah)
- Taman Negara (Malaysia) for nature tourism
- Lambir Hills National Park (Malaysia) for local use
- Tungku Abdul Rahman National Park (Sabah)
- A marine park in the Maldives
- Yala National Park (Sri Lanka)
- Tarutao National Park (Thailand)
- Cuc Phuong National Park (Vietnam)

3.3.5. Organization of training workshops in wildlife recreation development and management for tourist development corporations, national parks tourist offices, etc. (Action by World Tourism Organization, development agencies, etc.)

Objective 3.4. TO DEVELOP STRATEGIES FOR REDUCING LAND-USE CONFLICTS AT THE INTERFACE BETWEEN AGRICULTURE AND PROTECTED AREAS.

Activities at the National Level:

3.4.1. Greatly increase activity in fields of conservation education, extension and human ecological research in areas adjacent to protected reserves.

3.4.2. Cooperate with other land use agencies to plan development and resource utilization in such areas.

3.4.3. Develop buffer zones with gradients of resource use and resource protection from park to settled areas.

3.4.4. Recruit local people into the conservation agency itself, including opportunities for seasonal employment.

3.4.5. Implement programmes designed to lessen negative impacts arising from conservation, e.g. control of agricultural pests, stockraiders, man-eaters etc., by direct means or barriers.

3.4.6. Develop programmes designed to show benefits from conservation measures: e.g. provision and regulation of water flows, excess product offtake in buffer zones, tourism, and others.

3.4.7. Develop automatic procedures and expertise for undertaking environmental impact assessment investigations on all new developments in the areas adjacent to protected areas, as well as other areas of conservation importance.

Activities at the International Level:

3.4.7. Support action by government agencies to design, promote, and implement a few demonstration projects dealing with boundary conflict situations, including such areas as:

- Sundarbans (Bangladesh)
- Dudhwa National Park (India)
- Gir Forest (India)
- Manas Wildlife Sanctuary (India)
- Potential protected area development and management in areas of community forestry/shifting cultivation/wildlife values in Maghalaya (NE India)
- Proposed Rajaji National Park (India)
- Gunung Gede-Pangrango National Park (Indonesia)
- Kutai National Park (Indonesia)
- Lanjak Entimau Wildlife Sanctuary (Malaysia)
- Mt. Apo National Park (Philippines)

- Mt. Iglit-Mt. Baco and Balbalang Balbalasan National Parks (Philippines)
- Wilpattu National Park (Sri Lanka)
- Khao Yai National Park (Thailand)
- Huay Kha Khaeng (Thailand)
- Minh Hai Bird Sanctuary (Vietnam)

3.4.8. Promote independent environmental impact assessments for all development projects affecting natural ecosystems.

Goal 4 STRENGTHEN COOPERATION IN THE DEVELOPMENT OF CONSERVATION ACTIVITIES IN THE REGION

Objective 4.1. TO PROMOTE COOPERATION AMONG THE COUNTRIES OF THE INDOMALAYAN REALM TO ENSURE MORE EFFECTIVE MANAGEMENT AND PROTECTION OF THEIR NATURAL RESOURCES.

Activities at the National Level:

4.1.1. Interchange of ideas, information and expertise in conservation among nations, at senior policy, professional and research levels.

4.1.2. Offer frequent study tour and working tour facilities to examine conservation activities within the countries of the region.

4.1.3. Interchange expert staff between national management agencies, particularly where expertise is needed to address specific problems, such as:

- Elephant management in Indonesia (collaboration with Thailand, Burma, India, Sri Lanka);
- Rhinoceros management in Malaysia and Indonesia (collaboration with India);
- Crocodile management (expertise available from India on captive rearing and subsequent release);
- Musk deer farming (experts available in Korea, China);
- Feral buffalo control;
- Marine and coastal conservation issues in the region;
- Exchanges between the Wildlife Institute of India and the Conservation Management Training School of Indonesia;
- Elephant control and management in Sri Lanka, in collaboration with Burma, India, and Indonesia;
- Estuarine and tidal swamp conservation issues, including linkages with deforested catchment areas;
- Identification and management of threatened sites rich in wild relatives of economic plants through expertise from scientists in national biological/agricultural institutes;
- Use of barriers such as electric fencing in control of nuisance wildlife.

4.1.4. Free exchange of data, information and expertise regarding conservation activities.

4.1.5. Give support to international conservation agencies and conventions.

4.1.6. Ensure that permission to attend seminars, have study leave, and other means of international contact be given to qualified junior- as well as senior-level staff.

4.1.7. Ensure that appropriate representatives are provided the necessary support from government budgets to attend major international meetings, including meetings of CITES, IUCN, UNEP, ASEAN, and others.

4.1.8. Subscribe to both national and regional publications in the conservation field, and ensure that they are distributed to the appropriate field-level personnel.

4.1.9. Encourage conservation officers to contribute to newspapers, magazines, journals, and other media, thereby contributing to increasing awareness of conservation within the country and region.

4.1.10. Promote use of specialized training facilities by countries of the region other than the one in which the facilities are located: e.g. post-graduate courses at the Wildlife Institute of India, non-graduate courses at the Conservation Management Training School in Indonesia.

Activities at the International Level:

4.1.11. Provide scholarships to regional training institutes such as the Wildlife Institute of India and the Conservation Management Training School in Indonesia for supporting suitable trainees. (Action by Unesco, FAO, WWF, IUCN);

4.1.12. Establish a panel of experts from within the region to carry out advisory and consultancy assignments, facilitating exchange of ideas and building confidence in proven management techniques.

4.1.13. Support technical exchanges between countries, including training seminars, study tours, working assignments, etc., to provide the spread of good management techniques. (Action by UN system under TCDC programme.)

4.1.14. Support the establishment of an institutional focus for the scientific management of wildlife and other living resources within the Indomalayan Realm, with responsibilities for training, research, convening periodic meetings, publishing realm-based conservation reports, etc. (Action by FAO, supported by UNEP, IUCN, UNESCO and bilateral agencies.)

4.1.15. Support specific requirements for training in various aspects of protected area management, including:

- Exotic plant control in protected areas;
- Wildlife capture/translocation and marine survey and inventory in Vietnam;
- Elephant capture in Sri Lanka;

- Establishment of community development programmes around protected areas;
- Marine park management;
- Economic botany of wild crop relatives/medicinal plants in protected areas (including public awareness).

4.1.16. Sponsor seminars, workshops, etc. designed to bring professional managers in the region together on a regular basis. (Action by ASEAN, IUCN/CNPPA, Unesco, FAO), including:

- International Workshop on the Management of National Parks and Protected Areas in the Hindukush-Himalaya. (Action by ICIMOD, IUCN, WWF, King Mahendra Trust, Unesco);

- Convening of regular working sessions of IUCN's Commission on National Parks and Protected Areas in the Indomalayan Realm. (Action by IUCN.)

4.1.17. Promote linkages between university departments and institutions with an applied emphasis on wildlife biology and management and expertise in the wildlife education/interpretation fields.

4.1.18. Provide materials - including books, journals, etc. - to the managers of key protected protected areas.

Objective 4.2. TO DEVELOP BILATERAL/MULTILATERAL AGREEMENTS TO CONSERVE A SHARED FAUNAL OR FLORISTIC RESOURCE.

Activities at the National Level:

4.2.1. Develop, where appropriate, bilateral/multilateral treaties governing the conservation of shared or migratory natural resources.

4.2.2. Establish, where appropriate, joint protected areas along common boundaries to effectively conserve shared resources, possibly using the concept of "International Peace Park" as already implemented in several parts of the world. Indomalayan areas which might be appropriate for such joint action include:

- The Sundarbans of India and Bangladesh;
- The Manas Sanctuaries of India and Bhutan;
- Between Lahaul-Spiti (India) and Tibet (China), to protect species such as Tibetan gazelle, wild ass, and Tibetan wolf;
- Chitwan National Park of Nepal and Valmikinagar Sanctuary of India;
- The Mishmi Hills between China (Tibet) and India;
- Kaj-i-Nag Mountains of India and Pakistan;
- The Rann of Kutch of India and Pakistan;
- Kasalong Reserve Forests in northern Chittagong Hill Tracts of Bangladesh and adjacent regions of Assam, India;
- Lanjak-Entimau Reserve in Sarawak and Gunung Bentuang and Karimau reserves in West Kalimantan, Indonesia;

- A marine reserve between Sabah, Philippines, and Indonesia;
- The dipterocarp forests shared by Vietnam and Kampuchea;
- The Truong Son Range of Vietnam and Laos.

Activities at the International Level:

4.2.3. Provide any necessary coordinating mechanism for promoting inter-governmental cooperation to implement bilateral or multilateral agreements to conserve shared resources, including:

- Cooperation on management of species which migrate across adjacent borders, including elephants and tigers (Burma, Bangladesh, Bhutan, India); kouprey (Laos, Kampuchea, Vietnam, Thailand); and wild ass, wolf and Tibetan gazelle (India, China);
- Management of riverine ecosystems shared by countries (Tsangpo-Brahmaputra between India and China; Indus-Sutlej between China, India and Pakistan; Ganges-Padma and Brahmaputra-Jamuna between India and Bangladesh; River Naaf between Burma and Bangladesh; Mekong between China, Laos, Burma, Kampuchea, Thailand, Vietnam; Salween between Thailand and Burma; Red and Black rivers between China and Vietnam);
- Migratory species conventions, such as the migratory birds treaty between India and the USSR;
- Bilateral cooperation for the conservation of habitats containing wild relatives of economic plants: e.g. numerous tropical fruit tree species, wild rices, etc. along borders of Sabah and Sarawak and Sabah and Kalimantan;
- ASEAN Experts on the Environment (action by governments);
- Special efforts to develop the capacity to manage living marine resources;
- Coordinated management of World Heritage Sites which cover two countries (Manas, Sundarbans).

Goal 5. MONITOR THE IMPLEMENTATION OF THE CORBETT ACTION PLAN

Objective 5.1. TO REVIEW PROGRESS ON IMPLEMENTATION OF THE CORBETT ACTION PLAN THROUGH CONTINUOUS MONITORING OF REVELANT ACTIVITIES.

Activities at the National Level:

5.1.1. Promote the implementation of the Corbett Action Plan, through wide publicity among citizen groups and related government departments.

5.1.2. Contribute to international coordination through keeping IUCN/CNPPA informed on actions contributing to the Corbett Action Plan.

5.1.3. In each country, non-governmental conservation organizations to monitor implementation of the Corbett Action Plan.

Activities at the International Level

5.1.4. Promote the implementation of the Corbett Action Plan through wide publicity in the region and internationally. (Action by IUCN.)

5.1.5. Monitor the implementation of the Corbett Action Plan and up-date at future Indomalayan working sessions of CNPPA. (Action by IUCN.)

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Role of Traditional Agriculture in Preserving Biological Diversity

Gene Wilken
Colorado State University

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ROLE OF TRADITIONAL AGRICULTURE IN PRESERVING BIOLOGICAL DIVERSITY

by

Gene C. Wilken
Department of Economics
Colorado State University
Fort Collins, Colorado 80523

ROLE OF TRADITIONAL AGRICULTURE IN PRESERVING BIOLOGICAL DIVERSITY

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ABSTRACT

Traditional agriculture is characterized by small field size and reliance upon human or animal power to manage agricultural resources such as soil and water. Within these small-scale, low power systems farmers use biological diversity as a strategy to meet subsistence needs, exploit microenvironments, and mitigate environmental hazards. Diversity also is a response to resource constraints and crop requirements. Local demand for the many varieties of crops used in traditional foods encourages continued production of a wide range of species and races whereas international and national markets stress uniformity and discourage diversity.

Four general types of traditional agriculture are reviewed. Swidden fields may contain up to 100 crop types. Gathering and genetic exchanges with surrounding forests adds to exceptional diversity and creates locally-adapted varieties or landraces. Vegetatively complex dooryard gardens supply diverse subsistence needs and serve as experimental plots for new crops. Inter-cropping in semi-intensive, permanent field systems account for a wide range of plants while field edges, volunteer plots, and gardens provide new genetic material. Intensive systems compensate for small field size with varieties that support space- and time-saving technologies. Adaptation to local conditions and selection for specific purposes also produces varied livestock populations.

Traditional agriculture occupies a critical transitional or gatekeeper position between wild habitats and modern agricultural landscapes, and harbors a vast array of locally adapted landraces that constitute a valuable reservoir of genetic resources. The systems are threatened by rising populations and aspirations that emphasize increased production over diversity, and modernization and commercialization which stress uniformity rather than diversity. Abandonment of traditional foods further reduces demand for older antique or heritage crops.

Preserving traditional systems which use diversity as a strategy is one of the best ways to preserve biological diversity. In addition to favorable government and development policies, applied and basic research are needed to establish the ecologic and economic viability of traditional agriculture and thus ensure its place in contemporary and future societies.

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INTRODUCTION

Nature of the Problem

Concern over accelerated loss of species and races tends to focus on endangered large animals. Comparable concern for threatened plants has been late in developing, and for domesticated plants and animals is still negligible (Ayensu and DeFilipps 1978:1).

Yet the situation with respect to domesticates is no less ominous. Domestication has produced many new varieties distributed far from their original homes. But the apparent increase in diversity and range is misleading: many of the major food plants in contemporary use represent only a fraction of available genetic material in a particular species. Furthermore, new food, industrial, and medicinal needs continue to prompt world-wide searches for plants and animals that can satisfy new demands and specific growth and production characteristics (Chang 1984; DOS 1982:24; Walsh 1981).

The greatest range of natural diversity and source of new genetic material for most organisms is found in their centers of origin. Many of these centers are located in the tropics or subtropics and are faced with serious threats to survival from human activity (DOS 1982:18; Iltis 1972; Simmonds *et al*. 1976).

The lower latitudes also are the home of Less-Developed Countries (LDC's) where population growth and development efforts place enormous pressures on previously uncultivated regions.

Human populations exert pressure on wild plant and animal species by habitat destruction, excessive killing, and injudicious use or disposal of toxic materials. A fourth effect is peculiar to domesticated plants and animals. These special races are products of cultivation and human, rather than natural selection. If cultural practices are neglected, domesticated races disappear.

Although the problem of genetic loss is greatest in the tropics, the middle latitudes are not immune to the consequences. Ironically, the economic dominance of north over south is reversed in the ecologic sphere: the flow of biological materials between latitudes is overwhelmingly south to north both in short-term international trade and long-term genetic transfers. Economically developed societies are dependent upon tropically-grown industrial products (e.g., rubber; fibers), foods (e.g., coffee; sugar), and pharmaceuticals. The LDC's are much less dependent on middle latitude agricultural products.

Furthermore, in contrast to middle latitude plants which have transferred poorly to the tropics, low latitude biological materials now are fundamental to middle latitude agriculture.

For example, maize, rice, sorghum, beans, potatoes and many other crops are of tropical or subtropical origin.

The LDCs are still largely agrarian. Although most of them have technically advanced agricultural sectors, the majority of farmers operate on a small scale and use traditional methods. These traditional farmers occupy a unique position in the preservation of biological diversity. They are located in the tropics and subtropics where natural diversity and species extinctions are greatest. By migrating into new areas traditional farmers become one of the main causes of habitat destruction and species loss. But with justification, traditional agriculture could also be called diversified agriculture because of the mixture of crops in traditional fields and the interaction between cultivated and uncultivated environments.

In addition, traditional agriculture is one of the few institutions that actually creates new varieties or races. Over the centuries traditional farmers have identified hundreds of economic plants and animals in the wild and brought them into domestication. The process continues as farmers select for particular characteristics and develop locally adapted varieties, or landraces, that characterize traditional agriculture (Hanks 1972:16 ff). Thus, traditional farmers with their knowledge, technology, and strategies, emerge as a potent force for preserving and creating biological diversity.

Definition of Traditional Agriculture

The general characteristics of scale and technology will serve to differentiate traditional from modern farming. Traditional farms are small, usually containing less than five hectares (FAO 1971). But in addition, traditional farming systems are imbedded in local regions that supply most farm inputs, such as energy and materials, and absorb most farm outputs in local markets and subsistence consumption. Associated social and economic institutions also tend to be local, in striking contrast to the national and even international linkages of modern industrialized farming operations (Wilken 1981).

Traditional farmers rely upon human and animal power rather than fossil fuel powered equipment. Tools tend to be simple and generalized. Information on crop characteristics, resources (e.g., water, soil) management, and external factors (e.g., markets, government policies) comes mostly from local, rather than distant sources (Wilken 1974). These characteristics are basic to understanding the role of diversity in traditional farming.

DIVERSITY AS STRATEGY IN TRADITIONAL AGRICULTURE

The diversity of plants and animals in traditional agricultural systems has often been noted (Harwood 1979:12). But rather than a static characteristic, diversity can best be understood as a strategy in response to various opportunities and constraints within traditional systems.

Subsistence Production

Pure subsistence agriculture, in which there are no off-farm inputs or outputs, is rare (Wharton 1969). But since most traditional farm families rely on home production for a substantial portion of their food needs, dietary diversity must be supplied by production diversity. Usually basic grain or root crops occupy most of the field space. Secondary crops are planted with the main crop or along field edges and in dooryard gardens. Additional foods are collected from unused agricultural spaces or wild habitats. Draft and yard animals graze fallow fields and unused field edges, or convert garden and household waste into useful products.

Microenvironment Exploitation

Although the tropics have a reputation for monotonous climates, in fact there is a great deal of variation even over short distances. This is particularly true in mountainous regions which often are heavily settled and farmed. Temperature, rainfall, and soils change rapidly by elevation and slope aspect so that single villages or even individual farms may have lands in several distinct ecological zones. (Brush 1977a; 1977b). Even flatlands have marked changes over short distances (Denevan 1984;

Sternberg 1964). A diversity of environments is exploited with a diversity of crops and animals, each group of which is able to take advantage of a specific microenvironment.

Environmental Hazards

Similarly diversity is a strategy against environmental hazards. Typically farmers plant several varieties, especially of the basic crops, to insure against total loss in the event of adverse environmental events. For example, drought tolerant varieties or species provide a crop even if generally dry conditions or mid-summer droughts occur (Wilken 1982). Other varieties may be resistant to disease or insects. Animal adaptation to local conditions, especially stress elements such as heat, drought, and disease, are especially important. These attributes may come at the cost of lower overall production. But in the marginal world of traditional agriculture, security often outweighs maximum production and makes defensive diversity a practical strategy.

Resource Management

Sources of energy and information, and types of tools in traditional systems differ in quantity and kind from those of modern, industrialized agriculture. But in no way does this deny the effectiveness of traditional technology. By carefully manipulating soil, water, slope, and even microclimates traditional farmers enhance plant environments, extend crop ranges, and mitigate environmental hazards (Klee 1980; Stigter 1982; Wilken 1972; 1974). Partially controlling the physical environment also allows greater diversity of races and species. For example, small-scale irrigation permits water-using crops even in areas of low or uncertain rainfall and soil amendments compensate for otherwise limiting chemical or structural deficiencies. For reasons to be discussed later environmental management in modern industrialized farming systems reinforces the tendency to monocropping. But by adding new crops while retaining the old, locally adapted species and varieties, traditional farmers use technically enhanced environments to diversify even more.

Market Influences

In modern commercial agricultural sectors market demand and prices are dominant influences in resource allocation and production decisions. In traditional systems output is divided between autoconsumption and sale or exchange, and markets are only one of several factors in determining what will be produced. Nevertheless, demand in international, national, and local markets does enter into small-scale farm decisions.

Traditional farm contributions to international markets mostly are limited to products such as beverage crops (e.g., coffee, tea, cacao), fibers and other industrial crops (e.g., jute, hemp, rubber) special foods (e.g., bananas, sugar), and narcotics. Processing, distribution, and marketing demand standard products of consistent size, shape, color, sugar content, and so on. Although national markets may not be as rigid, they also favor product consistency and characteristics that meet the requirements of the distribution system.

In contrast, local markets reflect local tastes and may demand many different colors, flavors, or shapes. Traditional diets and dishes tend to evolve and elaborate over time: basic grains and roots are prepared in many forms and lesser foods appear as side dishes or sauces. Condiments and herbs, and festive or ceremonial dishes add to the complexity. Each dish may require special cooking qualities, colors, or other characteristics exclusive to a particular variety. The whole range of foods seldom can be produced on a single farm. Thus the needs of farmers coupled with those of non-food producing town dwellers create demand in local markets for many different types of products, including the older antique and heritage crops, and encourages continued production of a wide range of crops and varieties (van Epenhuijsen 1974).

Crop Requirements and Resource Scarcity

The field space and time, and nutrient and water requirements of the crop plants themselves are powerful stimuli for maintaining biological diversity on small-scale farms. Limited field size encourages intercropping of plants with differing nutrient and water, and horizontal and vertical space requirements. Two or three main crops may be grown in sequence each year (multiple cropping), each of which forms the center piece for a crop complex (intercropping) that is planted and harvested at different times (phased planting). Such close scheduling requires many crops of distinct growth habits and further adds to biological diversity on traditional farms.

Summary

Biological diversity emerges as an important strategy in traditional agriculture for coping with a series of environmental, dietary, and socioeconomic constraints. As such, it must be considered not simply as a passive characteristic of these systems but as a functional element.

MECHANICS OF DIVERSITY: TYPES OF TRADITIONAL AGRICULTURE

Traditional agricultural systems come in many forms and variations. Although they all share the characteristics of technology and scale discussed earlier, each achieves diversity in different ways. Only a few general models will be considered.

Swiddens

Swiddens (also shifting cultivation; slash-and-burn; long-fallow) are among the oldest and best known of traditional farming systems and are still practiced widely by some 200 million people over a combined area of 36 million km² (FAO 1957). Farmers clear their small fields, usually no more than two or three hectares, of trees or shrubs with axes and knives. After the residue dries it is burned, then crops are planted directly in the unplowed soil. Plots are cultivated for two or three years until yields decline due to nutrient depletion, weed competition, or disease or pest deprivations. Operations are then transferred to another site where the whole procedure is repeated (Conklin 1963; de Schlippe 1956; Spencer 1966; Watters 1971).

Crop diversity in swidden fields often is extraordinary. Although few systems can rival the 100 to 125 separate crop types found in the average Philippine Hanunóo plot (Conklin 1957:85), still the long-fallow systems tend to an astonishing number of species and varieties.

To the crops in cultivated fields must be added the harvests from "fallow" fields and uncleared areas. Farmers frequently visit old plots during the fallow cycle to gather residual crops that were deliberately planted for post-abandonment harvesting, adventitious crops (e.g., pioneering plants), animals that are attracted to clearings, and long-lived tree crops that were spared in the original clearing. With their mix of several stages, secondary successions are among the biologically richest communities on earth (Gómez-Pompa 1971). Swidden cultivators also exploit surrounding wild lands. Gathered plants and animals supply a significant proportion of food, fibers, medicines, and poisons (Posey 1985).

Swidden farmers work in what is essentially a forest environment: plots are initially cleared from the forests; much of the production actually comes from regenerating forests after plots are abandoned; and additional products are gathered from the surrounding forests. Thus, rather than spaces set apart, freshly cleared plots are simply one end of a continuum of environments that range from open fields to regrown forests, all of which are producing elements of the swidden system.

As might be expected biological material flows easily between the various elements. Although basic roots and grains often are introduced cultivars, other planted crops include semi-domesticated plants, perhaps pollinated by wild relatives, and edible, decorative, and medicinal plants found wild in the surrounding forest. The exchange is so intense that definitions of "farm" and "forest," "wild" and "domesticated" blur. As Spencer (1966:126) remarks, it is hard to determine "whether domesticates become feral, or whether nondomesticated plants are purposely grown in planted gardens."

The close proximity of cleared and regrown spaces and the exchanges of biological material between them create an environment favorable to the preservation and creation of diversity. Few useful plants in the forest or interesting crosses in the fields escape the attentive eyes of swidden farmers. Plant responses to environmental conditions such as shade or sunlight, moist or dry are carefully observed. The result is an on-going succession of introductions, crosses, and experiments that account for the plant diversity found in swidden fields.

Dooryard Gardens

Dooryard gardens are most common in Asia, least in Africa but are found in one form or another on all continents. They are maintained in a wide range of farming systems, from subsistence cultivators to labor- and capital-intensive market gardeners. Thus rather than a separate type, dooryard gardens are adjuncts to many other traditional systems. However, their role in preserving biological diversity merits special attention.

As their name indicates, dooryard gardens usually are located immediately adjacent to dwellings. Typically they are multi-layered complexes with relatively tall trees, such as coconut, mango, or papaya, shorter trees and tree-like plants and shrubs such as citrus, coffee, or banana, standing crops such as maize, beans, or tomatoes, ground-hugging crops such as squash or melons, and below-ground root and tuber crops such as manioc, potatoes, or taro. Other economic plants, such as bamboo or aloe, serve as living fences and sources of construction material. Within this floristic exuberance yard animals such as chickens, ducks, and turkeys reduce insect populations and garbage piles, add to soil fertility, and produce valuable eggs and meat.

Several characteristics account for the gardens' enduring popularity. They are convenient to living areas and receive attention from all family members, especially women. They offer a handy disposal area for household wastes and refuse, which results in a flow of nutrients and water into the garden space. Since most garden products are for household subsistence, farm families are free to plant whatever they please without concern for market constraints.

The net result of location, environment, and management is a space unrivaled in diversity. Kimber (1966) reports some 100 different plants in three gardens in Martinique. Slightly more than half of these were for food; the rest were for ornament, construction materials, medicines, and fibers. Similar diversity and complexity in dooryard gardens has been reported for South America, South, Southeast, and East Asia, and the Pacific (e. g., Anderson 1967; Fisk 1978; Wagner 1958).

Gardens also serve as test plots where chance discoveries in wild areas or new varieties from adjacent farming districts may be tried under reasonably controlled conditions and at little or no risk. Kimber (1978) argues that dooryard gardens served as loci for plant testing and domestication in the past and could continue to do this in a modern setting. The role of women in this process is particularly noteworthy.

Semi-intensive, Permanent Field

Most traditional systems combine basic grain or root crops and supplemental and cash crops on permanent fields that are cultivated every year. Although fields may be rotated or occasionally fallowed, they remain essentially in cultivation and do not require the repeated clearing of swidden plots. These systems encompass a great range of crop mixes, levels of technology, and land and labor inputs (e,g., Allan 1965; King 1973; Norman 1979).

Intercropping is common in many permanent field systems. It reduces risk of total crop failure, spreads labor loads, maximizes use of scarce land and water resources, reduces erosion, and achieves the synergistic effects of shading and nitrogen fixation (ASA 1976; ICRISAT 1981; Keswani and Ndunguru 1982). Intercropping also results in greater diversity within the farming system. Nor is the diversity in intercropped systems limited to planted crops. Farmers harvest adventitious seedings from previous years and collect "useful" weeds for fodder, medicine, or other economic uses (Chacon and Gliessman 1982).

Permanent field agriculture lacks the close proximity and intimate interactions with forests or other major uncultivated areas that characterize swidden farming. But field edges, fallow fields, canal banks and other micro-habitats offer distinctive environments and are sources of genetic material from the wild or feral plants that prosper there (Wilken 1970; 1977). Furthermore, farmers are not reluctant to experiment with chance finds from wild habitats, or new introductions from distant regions. First trials of new plants take place in field corners or the ubiquitous dooryard gardens where plant characteristics and requirements are easily observed. Plants that show promise subsequently are incorporated into regular field systems (Vermeer 1979).

Intensive Traditional Agriculture

Where land is scarce and markets or increasing populations create heavy demands traditional farmers increase production by intensifying resource management. Land leveling, terracing, irrigating and draining, and fertilizing or other soil improvements are among the many measures available for increasing yields per unit of area. Intensive resource management permits fuller use of available land, including marginal lands, by multiple cropping and advanced forms of intercropping.

Of the many types of intensive cultivation the wet rice or padi systems of Asia are most famous. Others include intensively-worked terrace, mound, and drained-field systems of Africa, Middle and South America, Asia, and the Pacific. Many market gardens that surround large cities in the Third World also fall into this category.

In intensive systems diversity as a strategy against environmental hazards and subsistence needs is partially replaced by resource management and market orientation. On the other hand, the need to maximize production from tiny parcels stimulates the search for varieties best-adapted to field microenvironments. In addition, scarce space can be used more effectively by reducing crop field time with quick-growing varieties, or transplanting from seedbeds. Other space-saving methods, such as inter-, phased-, storied-, or multiple-cropping have been mentioned. Agroforestry systems, where tree crops lower radiation loads or otherwise enhance crop environments, are special though notable cases (Wilken 1977), as are distinctive animal and aquaculture systems (Ruddle 1982). All of these techniques contribute to diversity which is expressed in individual fields and also in the mosaic of small farms in an area as each farmer arranges a particular mix to meet family needs, and local or microenvironmental conditions. Areas of intensive traditional agriculture contain some of the greatest concentrations of locally-adapted varieties. (Hanks 1972:16-19; Wilken 1969).

It might seem that diversity could also be a strategy against market risk: if prices for one crop are low, those for another may be high. But unless local eclectic tastes prevail, markets generally influence toward uniformity of product. The intensively managed horticultural farms that ring major cities in the Third World grow many different types of crops but of each, only the few varieties that have required market qualities such as appearance and perishability. In their pursuit of market acceptability traditional market gardeners may even use purchased seed, which terminates the process by which landraces are developed.

Agro-Pastoralism

A fifth type of traditional agriculture would include the grazing or agro-pastoral systems of arid and semi-arid lands. These range from full nomadism, in which operators have no permanent residence, through semi-nomadism, where animals are pastured for varying lengths of time and distance away from a permanent residence, to stationary ranching (Ruthenberg 1971, pp. 252 ff.). As is the case with crops, prehistoric husbandmen domesticated practically all of the animals in use today, and the process continues as contemporary pastoralists select those animals that are adapted to local environmental conditions and meet their objectives.

But the situation with animals differs somewhat from that of plants. The genetic base is narrower: of the several million animal species only about thirty of mammals and birds, and two of fish have been domesticated for use as food. With the exception of cows (3 species) the major producers (i.e., sheep, goats, pigs, chickens, ducks, and turkeys) are represented by a single species (Black 1983). In addition, the strategy of diversity with animals is not as pronounced. The number and variety of animals in an agro-pastoral operation does not compare with the range of plants in a cropping system, reproduction and development cycles of most animals are not as rapid (tree crops are an exception), and opportunities for crosses with wild stock and on-farm variation and selection are fewer (Beilharz 1983).

Nevertheless, traditional husbandmen have had a profound influence on developing and maintaining diversity in animals. Perhaps the greatest impact has come from transferring animals to different environments where adaptation to local conditions and selection for a range of objectives (of which food is only one) have resulted in great variation.

There are strong arguments for preserving the genetic resources of traditional animal husbandmen. These turn mostly on the premise that neither the conditions nor objectives of future animal husbandry can be anticipated, and that characteristics that now seem uneconomic may later prove valuable (Beilharz 1983). As with crop plants, the traditional world harbors an enormous number of races adapted to local conditions and objectives, and this resource deserves recognition and preservation.

Summary

Biological diversity is a fundamental strategy in traditional agriculture for meeting environmental, subsistence, and economic challenges. It is a dynamic process in which new combinations and races continue to be introduced from the wild or borrowed from other cultivated areas in the search for better adaptations to local conditions. Are the processes that create and maintain diversity in traditional agriculture still functioning? Absolutely! As long as the general constraints that determine production and marketing options remain unchanged, biological diversity will continue to be a primary strategy.

RELATIONSHIPS BETWEEN TRADITIONAL AND MODERN AGRICULTURE

Genetic Reserves

Are traditional processes for preserving biological diversity and incorporating new genetic material of significance to contemporary modern agriculture or to future needs? Again, absolutely! Historically the processes just described have accounted for practically all domesticated species and races of plants and animals. Secondly, many of the world's most important grains and root crops are of tropical or subtropical origin. Those that have been transferred to temperate latitudes usually are based upon only a few strains. Most new varieties emerging from modern plant breeding programs are generated from a few elite lines. The system continually narrows the germplasm base since it has minimal provision for introduction of new alleles into breeding populations (DOS 1982:15).

On the other hand, the centers of genetic diversity and the interactions between naturally occurring variation and human selection remain in the centers of origin which are essentially the domain of traditional farmers. Thus locationally and strategically traditional agriculture occupies a critical gatekeeper position between natural environments and variation, and the landscapes of modern agriculture. No other institution occupies this position, or contains the processes for creating new varieties and maintaining genetic diversity that are vital to the health and productivity of agriculture everywhere.

New Products

The same institution could also help bring new products to the world. Of the total number of edible plants, which may be on the order of 100,000, man at one time or another has used at least 3,000 for food. Yet only about 150 of these have ever been cultivated on a large scale and of these, fewer than 20 produce 90 percent of the world's food. Thus in addition to the main food crops, there exists another, larger pool of crops of unexplored potential (NAS 1975a; 1975b; 1977; 1979; Ritchie 1979).

Equally impressive lists of other economic crops could be developed. These include sources for industrial and pharmaceutical products, and forage and firewood crops. Although some of these have been tested and brought into production, the possibilities for new discoveries remain bright (Balandrin *et al.* 1985; Hinman 1984; Holman 1940; NAS 1977; 1980). Traditional farmers and plant collectors are among the most important links to this reservoir of diversity.

Similarly, the characteristics and potentials of traditional food and draft animals has been little explored. The popular image of native livestock as scrawny, unattractive beasts of low strength and yield ignores the likelihood that productivity is only one of several objectives of traditional breeders. Others, such as resistance to disease, heat, and drought, and ability to use rough forage, are of equal or greater importance. Some of these attributes may have application in modern agricultural sectors, especially as agriculture expands into marginal lands (Groenwold and Crossing 1975; McDowell and Hildebrand 1980; Ward and Sutherland 1980).

If animals common also to the developed world suffer from comparison, those restricted to traditional agriculture have been almost completely ignored. It seems likely that with research and proper breeding such animals as the camel, buffalo, llama, and perhaps even small animals such as guinea pigs could be made much more effective (Cockrill 1976; FAO 1977; Gade 1967; NAS 1981)

The arguments for preserving the animal resources of traditional agriculture turn mostly on the premise that neither the conditions nor objectives of future animal husbandry can be anticipated, and that characteristics that now seem uneconomic may later prove valuable (Beilharz 1983). As with crop plants, the traditional world harbors an enormous number of races adapted to local conditions and objectives, and this resource deserves recognition and preservation. Similarly, traditional animal and animal habitat management, a necessary corollary of resource use, merit closer examination (Anon 1983).

The argument for maintaining traditional agricultural systems as gatekeepers and preservers of animal resources is less compelling. Although selection for desirable characteristics continues, this function increasingly will be assumed by modern experimentation and guided by contemporary tastes and demands. Domestication of wild species is unlikely to be important.

Nevertheless, the enormous pool of diversity already present in the traditional world, the result of centuries of adaptation and selection, should cataloged and preserved before it is displaced by production-oriented breeds from higher latitudes. Distinctive characteristics should be maintained whether or not they have obvious economic value by today's standards. There are many forms that this could take, including semen and information banks, breeding populations, and farm parks (Beilharz 1983).

THREATS TO PRESERVATION OF DIVERSITY

Biological diversity is a basic strategy in traditional agriculture for coping with environmental and economic conditions. It follows that changes in these conditions will call forth different strategies and reduce dependency on diversity. The major factors of population growth and rising expectations, and commercialization seem most important.

Rising Populations and Aspirations

Population pressure and rising expectations are grouped here because both demand greater output. At national levels growing needs for food, foreign exchange, and resources for development encourage governments to stress yield over all other crop qualities. High production crops and resource management projects are justified by benefit-cost formulas that include factors for production but none for diversity. Experience with the Green Revolution supports this: the high yielding varieties (HYVs) represent only a few strains that respond well to high-input situations, and these are spreading rapidly in the LDCs (Dalrymple 1978). Although there is some dismay over the ecologic and economic effects of the Green Revolution, alternatives are not easy to propose.

Individual farmers similarly perceive few alternatives. Market disadvantages and government policies tend to keep prices low despite increased demand. The only way farmers can increase income is to increase output. Two routes are open: expansion or intensification. Since available land is scarce in already settled regions farmers migrate to uncultivated grasslands, shrublands and forests. Destruction of habitats by conversion to farmland is one of the better-known threats to biological diversity (Allen and Barnes 1985). Less dramatic but equally destructive is the shortening of fallow periods in swidden systems as a consequence of population pressure. The resulting deterioration of soil quality and natural vegetation alters animal and plant habitats and reduces biological diversity.

Setting aside reserves, or "freezing the genetic landscape" has been proposed (e.g.,Iltis 1974). But the obstacles are formidable: with pressure mounting on scarce agricultural land, Third World governments are hard pressed to deny access to uncultivated areas that should serve as genetic refuge areas (Raven 1976).

Intensifying production involves higher costs for labor and other inputs, which in turn leads to concentration on high value, market or export crops that can bear the costs and earn the cash needed to purchase more inputs. In some cases local markets can absorb the output and thus encourage continued production of a wide range of traditional varieties. But farmers who seek outlets in national or international markets will come under pressure to standardize.

Changing consumption habits, especially among urban dwellers but also rural folk, also discourages production of traditional varieties. Standardized processed foods are more accessible in cities, and prestige and promotion encourage substitution of nationally and internationally advertised products (Fleuret 1980; Kuhnlein 1981). The resulting reduced demand for local products puts additional pressure on small-scale farmers to abandon obsolete antique and heritage crops.

Modernization

Modernization of agriculture ranks next to productivity as a goal of agricultural development. But modern science and technology can also discourage diversity. Most powered field equipment is designed for monocultural operations. Lacking the flexibility of animal- or hand tools, it is ill-adapted to small-field, poly-cultural, traditional systems such as intercropping (Crossley and Kilgour 1983). Farmer experimentation and selection is discouraged by government laboratories and field stations, especially when the latter are promoted as superior to traditional methods.

REMEDIES

Population growth and modernization move traditional agriculture away from biological diversity. Since it is unlikely that either population levels or human aspiration will decline in the future, the question is whether anything can be done that would preserve biological diversity and the processes by which new genetic materials are introduced into agricultural systems. Several solutions have been proposed and will be briefly reviewed; others are based on the points made in this paper.

Gene Banks:

A review of the _ex situ_ solution of preserving germplasm in gene banks lies outside the scope of this paper. But two facts are germane to the discussion: gene banks are evidence of the value the developed world places preserving genetic divesity; and much of the materials in gene banks come from traditional farmers' fields (Plucknett, _et al._ 1983).

Gene banks are vulnerable to environmental hazards, economic breakdowns, and overt destruction. But in addition, gene banks cannot replicate the processes of variation. Like botanical gardens and zoos, they can maintain a variety of life forms but not the environment in which that variety developed. In the case of domesticates, the environment consists both of wild habitats and traditional fields and gardens.

A second set of solutions would attempt to preserve the processes, either by directly subsidizing farmers to maintain their traditional systems or by demonstrating that diversity is also economic and could maintain itself if given adequate research and government support.

Subsidies.

Paying farmers to maintain some level of diversity either directly or by support prices for a wide range of products has been suggested (DOS 1984:1984). The chances of success of such a program are slim. Subsidies support products that cannot survive in the marketplace because of high production costs or lack of market demand. These powerful negative factors and to offset them would require equally substantial commitments. Furthermore, since costs, prices, and demand for the sorts of antique and heritage crops considered here are unlikely to change, continuing subsidies would be necessary.

Ecologic and Economic Viability of Diversity.

Modern agriculture is accused of being dominated by technological and market influences, to the detriment of consumers, and relying too heavily on chemicals and fossil fuels, to the detriment of the environment. Other options have been proposed which consist of a blend of traditional methods enhanced by modern research. These go under several names such as agroecology, alternative or sustainable agriculture, and organic farming, and are advocated as more appropriate than modern methods for traditional farmers (Altieri 1983). The strong points of this approach are ecologic; economic research has not kept pace. Thus it has yet to be demonstrated that the proposed diversity-rich systems, even if enhanced by research, could achieve individual farmers' or national objectives of income or productivity.

Favorable Agricultural Policies.

National agricultural policies are determined by national needs and are molded around such goals as self-sufficiency, export earnings, and cost of food for urban populations, or by less-admirable considerations such as maintenance of landed and politically powerful elites. Preservation of traditional farm sectors to preserve genetic diversity for the benefit of the world community may not have much policy appeal to an LDC. Furthermore, even if traditional farm sectors were supported, perhaps for a combination of reasons such as rural employment, production, and diversity, there is no assurance that the farmers themselves would not change away from the strategy of diversity in response to other pressures and opportunities.

The technical and economic difficulties of framing policies that offer incentives to small-scale producers and also achieve national objectives are substantial (Pachico 1984). In addition, most local experiment and extension institutions are unacquainted with, or even distainful of traditional methods and thus, are poorly equipped to analyze and promote them. Less frequently mentioned but no less real is the threat to developers inherent in the idea that traditional technology might have something to offer. What exactly is the role of foreign or national experts who are told to learn from the farmers?

By the same token, agricultural policies that fail to include traditional farmers' perspectives and well-being are counter-productive. The traditional, small-scale sector is not an abstract consideration; it occupies an vital position in the food supply system of most Third World countries, employs a substantial proportion of the working force, and represents a resource well-worth developing. Preserving biological diversity is only part of its potential contribution to national economies and the world community.

BIOLOGICAL DIVERSITY AS NATIONAL AND INDIVIDUAL OBJECTIVE

The trick in devising effective programs is to translate international objectives into national objectives for the LDCs and ultimately into incentives for individual farmers. In addition, programs must be based upon a careful analysis of the dynamics of diversity in wild areas, and the role and processes of diversity maintenance in traditional agriculture. The following recommendations meet these criteria.

For most of the LDCs increasing agricultural production to meet the food needs of growing populations, earn export earnings, and achieve a degree of economic independence is a primary goal. Preserving biological diversity can be identified as a national objective if it can be shown to materially add to production. But most LDCs lack the resources to undertake the extensive and long-term research needed to develop yield-increasing varieties. What's needed are applied research and development programs supported by basic research.

Applied Research

Research programs that rely upon local genetic reserves to develop improved strains suited to local conditions should be given highest priority. The proposal has two components: incorporation of local genetic material, which would demonstrate the value of biological diversity, and development of locally adapted varieties for increased production. The approach also more closely approximates traditional genetic engineering, which produces plants adapted to local conditions, than does the introduction of strains that require substantial inputs to achieve maximum production (Barton and Brill 1983; Brill 1985; DOS 1982:40). Associated national inventory, collection, and preservation programs would identify local resources and also add to international collections.

There are important roles here for national agricultural organizations, international support agencies, and traditional farmers. Identification and collection of locally-adapted varieties would best be undertaken by trained extension agents. Experiment stations charged with improving strains and processing biological materials for international collections would benefit from technical and financial assistance from development agencies. Local farmer participation would be essential in identifying field samples, recommending needed characteristics, and testing improved varieties.

Development

Traditional agricultural practices should be incorporated into agricultural development projects whenever they can meet the objectives. This will be particularly difficult since it also would require coordination of international development agencies, national administrative units, and local farmers to a degree infrequently achieved. Development projects must specify that preserving diversity is an international and national goal. Local experiment and extension workers and advisors would have to learn and accept traditional techniques. The traditional farmers themselves should be brought into the process at the earliest stages of project design (Clarke 1978).

BASIC RESEARCH ON TRADITIONAL AGRICULTURE

Biological diversity is an integral component of traditional agriculture. The strategy and technology is difficult to transfer to other systems and if diversity is to be preserved, it is necessary that the traditional systems themselves be maintained. The times and circumstances are helpful: it seems unlikely that the millions of farmers on all continents that still use traditional methods will soon disappear or modernize. However, it still is essential to understand the forms and practices of traditional agriculture, and the role of traditional sectors in contemporary societies and potential for future development.

Research Needs

1. Establish a central clearing house of traditional data with international support similar to that enjoyed by the International Research Centers. Such a center could provide facilities for sharing traditional technology, especially between environmentally analogous regions. It could also participate in

international efforts to record local races of food and other economic crops, and to identify areas of needed work (Duke 1983; Leadley and Caye 1982; Plucknett and Smith 1982; 1984).

2. Systematic inventories and classification of traditional agricultural systems should have first priority. Field studies would include analyses of traditional techniques including crop selection, resource management, cultivation methods, and role of diversity. Initial target areas would be the major environments that have been especially productive of traditional methods and local races, such as the rice systems of monsoon Southeast Asia, maize systems of highland Middle America, and cattle systems of semiarid Central and East Africa. Field work would provide valuable experience with traditional technology for teams of young professionals from several sciences.

3. Similarly, evaluation of productivity, employment, and income-generating potentials of traditional systems, and of other goals such as nutritional balance and security would be essential. Traditional technology is part of an economic and social matrix, and can only be evaluated insofar as it meets goals and objectives peculiar to those conditions.

Prospects

Many public and private agencies are increasingly aware of the merits of traditional agriculture and already have implemented research programs designed to incorporate traditional technology in development. Among these are FAO, USAID and other national development agencies in Europe and Asia, several of the International Research Centers such as CIAT (Columbia), CIP (Peru), CIMMYT (Mexico), ICRISAT (India), and IITA (Nigeria), plus a number of non-governmental or private organizations (Interagency 1985). Recognition of traditional achievements and the need to incorporate traditional technology in development planning also is high (Brokensha 1980; Chambers 1983).

Thus, the environment for developing research on traditional agriculture,and programs for preserving traditional technology, including biological diversity, is favorable. The greatest need now is for coordination to establish linkages and roles for the various agencies, and for a clearing house to centralize information, identify gaps, and point to promising areas for future work. One of these promising areas surely would be on ways to encourage experimentation and preserve biological diversity in traditional agriculture.

REFERENCES

Allan, W., The African Husbandman. Edinburgh: Oliver & Boyd, 1965.

Allen, J. C., and Barnes, D. F., "The Causes of Deforestation in Developing Countries." Annals of the Association of American Geographers 75:163-184, 1985.

Altieri, M. A., Agroecology: The Scientific Basis of Alternative Agriculture. Berkeley: University of California, Division of Biological Control, 1983.

American Society of Agronomy (ASA), Multiple Cropping. Madison: ASA Special Publication No. 27, 1976.

Anderson, E., Plants, Man and Life. Berkeley: University of California Press, 1967.

Anon, "Back to Beduin Basics." International Agricultural Development 3:21, 1983.

Ayensu, E. S., and DeFilipps, R. A., Endangered and Threatened Plant of the United States. Washington, D. C.: Smithsonian Institution and World Wildlife Fund, 1978.

Baldandrin, M. F., et al., "Natural Plant Chemicals: Sources of Industrial and Medicinal Materials." Science 228:1154-1160, 1985.

Barton, K. A., and Brill, W. J., "Prospects in Plant Genetic Engineering." Science 219:671-676, 1983.

Beilharz, R. G., "Conservation of Animal Genetic Resources." In Peel and Tribe (eds.), 1983, pp. 93-105._

Black, J. L., "Evolutionary Adaptations and their Significance in Animal Production." In Peel and Tribe (eds.), 1983, pp. 107-132.

Brill, W. J., "Safety Concerns and Genetic Engineering in Agriculture." Science 227:381-384, 1985.

Brokensha, David W., Warren, D. MN., and Werner Oswald (eds.), Indigenous Systems of Knowledge and Development. Lanham: University Press of America, Inc., 1980.

Brush, S. B., "Farming the Edge of the Andes," Natural History 86:32-41, 1977a.

- - - , Mountain Field and Family: The Economy and Human Ecology of an Andean Valley. Philadelphia: University of Pennsylvania Press, 1977b.

Chacon, J. C., and Gliessman, S. R., "Use of the 'Non-Weed' Concept in Traditional Tropical Agroecosystems of South-Eastern Mexico." Agroecosystems 8:1-11, 1982.

Chambers, Robert, Rural Development: Putting the last First. London: Longman Group, Ltd., 1983.

– – –, "Agricultural Research for Resource-Poor Farmers: The Farmer-First-and-Last Model." Agricultural Administration 20:9:1-30, 1985.

Chang, T. T., "Conservation of Rice Genetic Resources: Luxury or Necessity?." Science 224:251-256, 1984.

Clarke, W. C., "Progressing with the Past: Environmentally Sustainable Modifications to Traditional Agriculture," in Fisk (ed.), 1978, pp. 142-57.

Cockrill, W. R., The Buffaloes of China. Rome: Food and Agriculture Organization of the United Nations, 1976.

Conklin, H. A., Hanunóo Agriculture: A Report on an Integral System of Shifting Cultivation in the Philippines. Rome: FAO Forestry Development Paper No. 12, 1957.

- - - , El Estudio del Cultivo Roza. Washington, D. C.: Pan American Union, Estudios y Monografias 11, 1963.

Crossley, P., and Kilgour, J., Small Farm Mechanization for Developing Countries. Chichester: John Wiley & Sons, 1983.

Dalrymple, D. G., Development and Spread of High-Yielding Varieties of Wheat and Rice in the Less Developed Nations (6th ed.). Washington, D. C.: U. S. Department of Agriculture, Foreign Agriculture Economic Report No. 95, 1978.

Denevan, W. M., "Ecological Heterogeneity and Horizontal Zonation of Agriculture in the Amazon Floodplain." Frontier Expansion in Amazonia, Schmink, M., and Wood, C. H. (eds). Gainesville: University of Florida Press, 1984, pp. 311-336.

Department of State (DOS), Proceedings of the U. S. Strategy Conference on Biological Diversity. Washington, D. C.: Publication 9262, 1982.

- - - , United States Activities Related to in Situ Conservation of Genetic Resources. Washington, D. C.: 1984.

de Schlippe, P., Shifting Cultivation in Africa: The Zande System of Agriculture. London: Routledge and Kegan Paul, 1956.

Duke, J. A., "The USDA Economic Botany Laboratory's Data Base on Minor Economic Plants." Plants: The Potentials for Extracting Protein, Medicines, and other Useful Chemicals (Workshop Proceedings). Washington, D. C.: Congress of the United States, Office of Technology Assessment, 1983.

Fisk, E. K. (ed), The Adaptation of Traditional Agriculture: Socioeconomic Problems of Urbanization. Canberra: The Australian National University, 1978.

Fleuret, P., and A., "Nutrition, Consumption, and Agricultural Change." Human Organization 39:250-260, 1980.

Food and Agriculture Organization (FAO), "Shifting Cultivation," Unasylva 11:9-11, 1957.

- - - , Report on the 1960 World Census of Agriculture, Vol. 5. Rome: FAO-UN, 1971.

- - - , The Water Buffalo. Rome: FAO Animal Production and Health Series No. 4, 1977.

Gade, Daniel W., "The Guinea Pig in Andean Folk Culture." Geographical Review 57:213-224, 1967.

Gilles, Jere Lee, "Planning Livestock Development: Themes from Indigenous Systems." Agricultural Administration 11:215-25, 1982.

Gómez-Pompa, Arturo, "Posible Papel de la Vegetación Secundaria en la Evolución de la Flora Tropical." Biotropica 3:125-35, 1971.

Groenewold, H. H., and Crossing, P. R., "The Place of Livestock in Small Farm Development." World Animal Development Review 15:2-6, 1975.

Hanks, L. M., Rice and Man: Agricultural Ecology in Southeast Asia. Chicago: Aldine-Atherton, Inc., 1972.

Harwood, R. R., Small Farm Development. Boulder: Westview Press, 1979.

Hinman., C. W., "New Crops for Arid Lands." Science 225: 1445-1448, 1985.

Holman, H. J., A Survey of Insecticide Materials of Vegetable Origin. London: Imperial Institute, 1940.

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Proceedings of the International Workshop on Intercropping. Hyderabad: 1981.

Iltis, H. H., "Shepherds Leading Sheep to Slaughter," American Biology Teacher 34:127-130, 137; 201-205, 221, 1972.

- - - , "Freezing the Genetic Landscape - The Preservation of Diversity in Cultivated Plants as an Urgent Social Responsibility of the Plant Geneticist and Plant Taxonomist." Maize Genetics Cooperation Newsletter 48:199-200, 1974.

Interagency Task Force, U. S. Strategy on the Conservation of Biological Diversity. [Washington, D. C.], 1985.

Keswani, C. L., and Ndunguru, B. J., Proceedings of the Second Symposium on Intercropping in Semi-Arid Areas. Morogoro: International Development Research Center, 1982.

Kimber, C, "Dooryard Gardens of Martinique." Yearbook, Association of Pacific Coast Geographers 28:97-118, 1966.

- - - , "A Folk Context for Plant Domestication: Or the Dooryard Garden Revisited." Anthropological Journal of Canada 16:2-11, 1978.

King, F. H., Farmers of Forty Centuries. Emmaus, Pennsylvania: Rodale Press, Inc., 1973 [1911].

Klee, G. A. (ed), World Systems of Traditional Resource Management. New York: V. H. Winston & Sons, 1980.

Kuhnlein, H. V., "Dietary Mineral Ecology of the Hopi." Journal of Ethnobiology 1:84-94, 1981.

Leadley, S. M., and Caye, V. M., "Information Dissemination: A National Clearing House for Small Farms." Research for Small Farms: Proceedings of the Special Symposium, Kerr, Jr., H. W., and Knutson, L. (eds). Beltsville: U. S. Department of Agriculture, 1982, pp.263-264.

McDowell, R. C.; and Hildebrand, P. E., Integrated Crop and Animal Production: Making the Most of Resources Available to Small Farms in Developing Countries. New York: The Rockefeller Foundation Working Papers, 1980.

Myers, N., A Wealth of Wild Species. Boulder: Westview Press, 1983.

Nabhan, G. P., "Native Crop Diversity in Aridoamerica: Conservation of Regional Gene Pools." Economic Botany (in press).

National Academy of Sciences (NAS), Underexploited Tropical Plants with Promising Economic Value. Washington, D. C.: 1975a.

- - - , The Winged Bean: A High-Protein Crop for the Tropics. Washington, D. C.: 1975b.

- - - , Leucaena: Promising Forage and Tree Crop for the Tropics. Washington, D. C.: 1977.

- - - , Tropical Legumes: Resources for the Future. Washington, D. C.: 1979.

- - - , Firewood Crops: Shrub and Tree Species for Energy Production. Washington, D. C.: 1980.

- - - , The Water Buffalo: New Prospects for an Underutilized Animal. Washington, D. C.: National Academy Press, 1981.

Norman, D. W., "Rationalizing Mixed Cropping under Indigenous Conditions: The Example of Northern Nigeria." Journal of Development Studies 11:3-21, 1974.

Norman, M. J. T., Annual Cropping Systems in the Tropics. Gainesville: University Presses of Florida, 1979.

Pachico, D., "Bean Technology for Small Farmers: Biological, Economic and Policy Issues. Agricultural Administration 15:71-86, 1984.

Peel, L., and Tribe, D. E., Domestication, Conservation, and Use of Animal Resources. Amsterdam: Elsevier Science Publishers, B. V., 1983.

Plucknett, Donald L., and Smith, Nigel J. H., "Agricultural Research and Third World Food Production." Science 217:215-220, 1982.

- - - , and Smith, Nigel J. H., "Networking in International Agricultural Research." Science 225:989-993, 1984.

- - - , et al., "Crop Germplasm Conservation and Developing Countries." Science 220:163-169, 1983.

Posey, D. A., "Native and Indigenous Guidelines for New Amazonian Development Strategies: Understanding Biological Diversity through Ethnoecology." Change in the Amazon (vol. 1), Hemming, J (ed). Manchester: Manchester University Press, 1985, pp. 156-181.

Raven, P. H., "Ethics and Attitudes." Conservation of Threatened Plants, Simmons, J. B., et al. (eds), New York: Plenum Press, 1976, pp. 155-179.

Ritchie, G. A.(ed), New Agricultural Crops. Boulder: Westview Press (American Association for the Advancement of Science), 1979.

Ruddle, Kenneth, "Traditional Integrated Farming Systems and Rural Development: The Example of Ricefield Fisheries in Southeast Asia." Agricultural Administration 10:1-11, 1982.

Ruthenberg, Hans, Farming Systems in the Tropics. Oxford: Clarendon Press, 1971.

Simmons, J. B., et al., Conservation of Threatened Plants. New York: Plenum Press, 1976.

Spencer, J. A., Shifting Cultivation in Southeastern Asia. Berkeley: University of California Press, 1966.

Sternberg, H. O., "Land and Man in the Tropics." Proceedings of the Academy of Political Science 27:319-329, 1964.

Stigter, C. J., "Manipulation of Microclimate in Tanzanian Traditional Farming." National Agrometeorology Committee (Tanzania) Newsletter No. 7, 1982.

van Epenhuijsen, C. W., Growing Native Vegetables in Nigeria. Rome: Food and Agriculture Organization of the United Nations, 1974.

Vermeer, D. E., "The Tradition of Experimentation in Swidden Cultivation Among the Tiv of Nigeria." Applied Geography Conferences (Vol. 2), Frazier, J. W., and Epstein, B. J. (eds). Binghamton: State University of New York, 1979.

Wagner, P. L., Nicoya: A Cultural Geography. Berkeley: University of California Publications in Geography Vol. 12, No. 3, 1958, pp. 195-250.

Walsh, John, "Genetic Vulnerability Down on the Farm." Science 214:161-4, 1981.

Ward, G., and Sutherland, T. M., and J. M., "Animals as an Energy Source in Third World Agriculture." Science 208:570-574, 1980.

Watters, R. F., Shifting Cultivation in Latin America. Rome: Food and Agriculture Organization, FAO Forestry Paper No 17, 1971.

Wharton, Jr., C. R., "Subsistence Agriculture: Concepts and Scope." Subsistence Agriculture and Economic Development, Wharton, Jr., C. R. (ed). Chicago: Aldine Publishing Co., 1969, pp. 12-20.

Wilken, G. C., "Drained-Field Agriculture: An Intensive Farming System in Tlaxcala, Mexico. Geographical Review 59:215-241, 1969.

- - - , "The Ecology of Gathering in a Mexican Farming Region." Economic Botany 24:286-295, 1970.

- - - , "Microclimate Management by Traditional Farmers." Geographical Review 62:544-566, 1972.

- - - , "Some Aspects of Resource Management by Traditional Farmers." Small Farm Agricultural Development Problems, Biggs, H. H., and Tinnermeier, R. L. (eds). Fort Collins: Colorado State University 1974, pp. 47-59.

- - - , "Integrating Forest and Small-Scale Farm Systems in Middle America." Agro-Ecoystems 3:291-302, 1977.

- - - , "The Fallacy of Labour/Land Comparisons of Agricultural Productivity." Perspectives in Agricultural Geography, Vol. 4, Mohammad, N. (ed). New Delhi: Concept Publishing Co., 1981. pp. 455-461.

- - - , Agroclimatic Hazard Perception, Prediction, and Risk-Avoidance Strategies in Lesotho. Boulder: University of Colorado, Natural Hazard Research Working Paper Series NO. 44, 1982.

Contract Paper No. 5

Compatibility of Development and the In-Situ Maintenance of Biological Diversity in Developing Countries

Richard Saunier and Richard Meganck
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COMPATIBILITY OF DEVELOPMENT AND THE IN-SITU MAINTENANCE OF BIOTIC DIVERSITY IN DEVELOPING COUNTRIES

By

Richard E. Saunier and Richard A. Meganck [1/]

INTRODUCTION

Several observations, resolutions, and guidelines from recent meetings relate to in-situ maintenance of biotic diversity (FAO, 1979; U.S. Department of State, 1982; WRI, 1984; Inter-Parlimentary Union, 1985). All make the points that continued survival of mankind will depend on the use of this diversity; that humid tropical regions hold the vast majority of the potentially useful genetic material; and that therefore setting aside "wildlands" as reserves in these areas is of urgent priority. Some would curtail any development activity short of conservation that would attempt manipulation of the ecosystems in question (U.S. Department of State, 1982). This guideline, based on the point of

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[1/] Respectively, Environmental Management Advisor and Natural Resources Specialist, Department of Regional Development, Organization of American States (OAS). The views expressed in this paper are the authors' and may not represent those of the OAS.

view that until methods are available to easily discern which of the millions of species and varieties will have economic value, conservation of wildlands should be the primary means for maintenance of these resources.

In-situ maintenance of genetic resources through the establishment of conservation areas does offer a number of advantages over off-site methods:

- Broad brush coverage--the assumption being that if a worldwide system of protected areas is completed, a majority of indigenous species and systems will be protected, if only fortuitously. This method covers the unknowns until such a time that methods are found for their investigation and utilization (Burley, 1982).
- Natural selection and community evolution continues and new genetic material is produced (Oldfield, 1984); and,
- Potential economic or "exchange" benefits are stored by the country maintaining the species until a need develops; economic benefits are provided through the domestication and improvement of crops and livestock from wild gene pools (Prescott-Allen and Prescott-Allen, 1985).

While citing the need for a large diversity of biotic resources to provide the basis for development efforts, the tenor of these conferences and of numerous individual works (Lovejoy, 1979; Myers, 1984; Hahn, 1984) reflects a concern that in-situ methods for the maintenance of biotic diversity may not be compatible with other development activities.

An analysis of these observations, resolutions, and guidelines, a consideration of the development realities of much of the developing world, and a review of development planning methods suggests that although often absent or rare at present, a degree of compatibility between biotic resources maintenance and other development activities could be achieved. It will depend, however, on a number of attitudinal, if not conceptual adjustments on the part of many who call for *in-situ* maintenance as well as on a clearer understanding of the rationale behind *in-situ* maintenance by those whose activities prohibit or otherwise conflict with such measures.

IN-SITU MAINTENANCE AND CONSERVATION AREAS: THE PROBLEM

As of 1982, some 2 600 parks and protected areas including in excess of 4 million square kilometers had been established in 124 nations (Harrison, *et*. *al*., 1982). Combined with smaller conservation areas, including state parks and private reserves among other categories, the number of conservation units exceeds 4 000 (WRI, 1984).

Furthermore, an overview of existing protected areas at the broadest level reveals that all eight Natural Realms and 14 Biomes categorized by Udvardy (1975, 1984) are represented worldwide. Only 16 of 227 Biogeographic Provinces, the majority in developing countries, are not receiving any real degree of official protection. New protected areas should be established as a matter of priority in the remaining Provinces to ensure that the broadest possible range of genetic resources is available should science or industry require.

Globally, then, the possibilities for *in-situ* maintenance through the use of national parks, equivalent reserves and other conservation areas *appear* to be somewhat favorable. However, the status of these protected areas is not consistently good. Indeed, in many developing countries official protection of an area is often an invitation for people to move in, claim and work a parcel of land. Invasion of protected areas by colonists and shifting agriculturists are regularly identified by administrators as important management problems in Latin America (Wetterberg, *et*. *al*., 1985); in Indonesia (Robinson and Rustandi, 1982); and in Africa (Monfort and Monfort, 1984). Worldwide, the IUCN list of endangered protected areas indicates several additional activities as threatening their integrity (Nicholson, 1984). In general order of importance these are: water development, mining, road construction, livestock grazing, poaching, settlement, occupation by rebel and military forces, inadequate management, logging and other removal of vegetation, fire, civil unrest, and pipeline and powerline construction.

In most developing countries there is a paucity of technically trained personnel, an inability to undertake and execute long range planning, scanty public awareness and support for protected area goals, inadequate physical infrastructure, and neither the opportunity nor the means to relocate unsponsored colonists. In almost all areas where legislation is adequate, neither budget nor trained personnel to enforce regulations are sufficient. And, because of an absence of basic resource information, effective management is inhibited and by and large the integrity of protected areas is impossible to insure even in the short term (Barriga and Byers, 1982).

Losses from conservation areas are therefore high. Eckholm (1978) indicated that there were 30 000 peasant farm families living within the national parks, forest reserves, wildlife refuges, and other protected areas of Venezuela alone. In El Salvador, peasant colonists had taken over 50 percent of the Montecristo Cloud Forest National Park by the early 1970's (Daugherty, 1972). La Macarena National Park in Colombia has been reduced in size from more than 1 300 000 ha in 1948, when it was established, to slightly more than 500 000 ha as a result of unstemmed invasion (Wetterberg and Meganck, 1978; IUCN, 1982). The responsible agency simply altered the boundaries as the wave of colonists advanced since no other solution was feasible (IUCN, 1982). Nearly half of the 15 000 ha Tayrona National Park on the Caribbean coast of Colombia was sold to land speculators in 1980 by private individuals claiming land titles prior to the parks establishment in 1964. While the agency in charge has declared the transfers invalid, the legality will have to be challenged in court since outstanding claims were apparently never officially resolved (Sierra Club, 1981).

The problem in Haiti has reached such proportions that an estimated 7 percent is all that remains of the country's original forest cover (Lugo, et. al., 1981). As early as 1946 Mexico's reserves were suffering from an invasion by people without arable land or sources of firewood (Vogt, 1946). Similar examples can be cited from other regions. In Rwanda, agriculture pressure has reduced total forest cover to 6 percent and hundreds of hectares of the Chateau d'Eau forest region-with its unique land fauna and flora-are being converted to agriculture each year (Anon., 1985). The Virunga ecosystem, Africa's first National Park (1935), has suffered the same fate: some 40% of the park had been converted to cropland by 1968 (Weber, 1985). In the Ivory Coast's Tai National Park, where an estimated 10 percent of all plant species are found nowhere else, migrants from Mali and Upper Volta had taken over 25 percent of its original extension by 1981 (Anon., 1981). Even on the rare occasions when the requisite political backing for resettling colonists outside a reserve and securing the boundaries is forthcoming, associated costs are so high that few nations can follow through with plans to do so. Thus many of the protected areas in the developing world are protected with legal standing and enabling legislation, but a lack of management essentially renders the objectives unreachable.

INCOMPATIBILITY AND ITS CAUSES

The above only demostrate incompatibility. The reasons for incompatibility are complex and include, of course, those related to population pressure-perhaps the most complex of all. It is because of this complexity rather than its degree of importance that it is not directly discussed here. The reasons for incompatibility also include differences in the perceived needs of the various parties, unfocused objectives on the part of many conservation efforts, problems of setting priorities under restrictive budgets, lack of broad-based public support, conflicting policy instruments, administrative barriers, competition between agencies, and often exagerated fears from both sides.

1. Conflicting Needs.

Human life quality depends on the satisfaction of a number of different kinds of needs: physical needs (adequate nutrition and shelter; information, training, transportation, and other services which guarantee their satisfaction); protection from aggresion (adverse weather, pathogins, trauma, toxic materials, foreign occupation, unauthorized use of natural resources, attacks on the collective social, cultural, economic, and political integrity, etc.); and, spiritual (Goulet, 1971).

Needs, of course, vary by culture, age, sex, season, climate, education, income, and therefore, by individual and group. Even within these, some needs must be satisfied before others are felt. It is often difficult to distinguish between needs and wants; and, lack of information and understanding often undo efforts to improve quality of life (McHale and McHale, 1977). Obviously in-situ maintenance of biotic resources is a development strategy which will lead to the satisfaction of a number of needs cited above. The many activities required to satisfy all of these needs will affect and will often conflict with in-situ maintenance of biotic diversity as well as with other development activities. At the specific level, Meganck (1975) found that park rangers in Colombia were unwilling to enforce poaching or timber cutting laws in remote areas since they also relied on these activities for survival. At a more general level, "The relentless pressures that arise where basic human needs are not met can erase the resource base from which man must inevitably gain his sustenance" (Tolba, 1982, p. 11).

2. Conflicting Responses: Development.

Development--socially, economically, and culturally is the process of improving human life quality through active manipulation of complex human environments. Unfortunately there is nothing in its definition and seldom anything in its execution that states that the costs and benefits are to be equitable or justly distributed.

Development is also the array of activities that lead to the use, improvement, or conservation of natural and economic goods and services. Natural goods and services (Table 1) are generally equivalent to natural resources except that they have been further defined and identified by specific sectors as having value for life quality improvement (Saunier, 1984). Although they often have economic value, they may also have social, cultural, scientific or ecosystem maintenance values which are mostly non-priced.

Incompatibility occurs because the use, enhancement or conservation of a particular good or service also prohibits the use of, impoverishes, or destroys other goods and services from the same system that are of interest to other groups. Consequently, most development activities --including conservation-- that are designed by one sector to improve the quality of life for its constituency will interfere in a variety of ways with the efforts of other sectors to improve their quality of life (Saunier, 1979; Meganck and Saunier, 1983). Incompatibility between development activities is thus not unique to conservation--any set of development activities will act in this way. This happens despite the range of related benefits provided by protected areas (recreation, education and research sites, water and soil conservation, etc.) as outlined in Table 2 (Thelen and Miller, 1976). Problems of compatibility exist even within this group of objectives. Problems of compatibility with other activities also obviously exist. These can be hinted at by comparing Tables 1 and 2. Those same lands that provide the services of a genetic resource bank may also provide nutrients and space for agriculture and ranching; biomass for harvest as lumber and firewood; and means for the dilution, transport, and treatment of wastes. All of these services are available from most large natural ecosystems and we cannot ignore them. The temptation in times of crises and weakened economies is to: (1) decide against many of those goods and services that require "conservation"--the value of which is often accrued in the future--and for others that relate to agriculture, ranching, forestry, and industrial development--which tend to have more immediate benefits; and (2) to overtax the natural goods and services instead of investing in economic goods and services.

For example, in rural and frontier areas such as the humid tropics, development activities place emphasis on the use of natural goods and services while in urban areas and in hi-tech agriculture, the mix changes to include a greater use of economic goods and services by means of additional subsidies of energy and materials. Unfortunately, in many developing countries, migration to urban and frontier areas alike has outstripped the capacities of those countries to provide the necessary economic goods and services (i.e., sewage treatment in urban areas and fertilizer in rural areas). In order to acquire a degree of life quality in the short-term, natural services such as riverine transport of contaminants and slash and burn "fertilization" continue to be used. In doing so, thresholds are soon reached, and existing urban, rural, and natural ecosystem structure and function breakdown, even more goods and services are lost or impoverished, and conflict is generated. Conflict and compatibility thus depend upon which of the many needs are to be addressed, the mix of goods and services available to meet those needs, the modification of this mix caused by development activities that have been designed and executed to meet those needs, and the degree of success in their execution.

Insufficient subsidies for the growth, migration, and concentration of populations are thus fundamental problems in much of the developing world. The larger cities: Mexico, Sao Paulo, Cairo, Manila, etc. are, of course, examples. Air pollution endangers health; rivers become sewers, poor housing springs up within and around the cities, and urban expansion continues at the cost of productive agriculture land and wild areas. Small cities in small countries are not immune. In the Caribbean, such activities--often combined with the effects of natural phenomena such as hurricanes and volcanic eruptions--have destroyed wetlands, brought about siltation of coral reefs and have taken their toll on biotic diversity (Nicholls, 1985).

Development activities in rural areas are also increasingly conflictive--in part because of population growth but more often perhaps because of population migration. Rural population growth rates in Latin America dropped from 1.3 percent in 1950-55 to 0.3 percent in 1975-80, although there are higher subregional differences in those areas where the man/land ratios are the worst. (The ratio of arable land to population in Southern Latin America ~~is~~ more than 1.0 ha per capita, five times that of the Caribbean region and three times greater than of Central American or the Andean Zone). Migration between rural areas is significant: in the last decade, rural population in Brazil dropped by only 2 million because of population movement into the Amazon Basin. Whatever the case, population levels in developing nations continue to be greater than the ability to provide economic goods and services (Holdgate, et. al., 1982; UNEP, 1985a). In addition, other factors contribute to the high ratios of population to arable land in much of the developing world. Those include mountainous lands or deserts not suitable for occupation without costly inputs; large, unused parcels of land of single ownership; and poorly developed infrastructure over large areas that make them inaccesible.

As a response, expansion of the agricultural land base becomes a high priority in most developing countries through organized colonization actions in sparsely settled areas such as deserts (Kishk and Bailey, 1985) and tropical lowlands (Hanson and Koesoebiono, 1977). As in any development scheme, these activities initiate a process of ecosystem change that is particularly costly to genetic diversity unless specific efforts are made on its behalf as a part of the overall development effort.

3. Unfocused Objectives.

The objectives of in-situ maintenance of genetic resources--if they are to be reached--must be explicit and specific. It is not always clear, however, whether proponents of in-situ maintenance are interested in biotic diversity or whether their interest is in broad scale nature conservation. Though closely related and often allied, they are not the same (UNEP, 1980). A large number of the species that are used as examples of wildland genetic resource discoveries are neither wildland species nor recent discoveries at all. Instead, they are well-known "weed" species, or they have been discovered along hedge rows, in cemeteries, and under thorn bushes, or they are primitive species growing in isolated farm plots of well-known cultures or in the gardens of isolated cultures. Additionally, many of the species that are used to justify wildland conservation in the humid tropics are really from arid and semiarid areas.

For example, seldom has there been a discussion on genetic resources since the discovery of the perennial diploid teosinte (Iltis, et. al., 1979) that has not included it as a well justified example of the value of wild genetic material. Based on this example, the point is often made of the need to protect wild species and their habitats--particularly the humid tropics. Protection of certain wildlands or the preservation of specific humid tropical forest ecosystems may well be valuable tactics to meet the objectives of genetic resource maintenance, including the important ecosystem processes necessary for evolution. Likewise, protection of certain wildlands and specific humid tropical ecosystems may be valuable for a combination of reasons including genetic resource maintenance.

Though not mutually exclusive, however, logic leads to other conclusions if the discovery of this teosinte is to be used as the example. First, though a wild species, it was not encountered in the "wild". Rather it was growing on the edges of corn fields and in grazed pastures. Second, though it was "discovered", it was not unknown. Indeed, it has several common names and is used as a corn substitute by the local population; and third, although the latitud of its major location (19°31'N) is in the tropics, the life zone where it occurs is altered pine-oak woodland and not tropical rainforest (Iltis, et. al., 1979).

The issue is confused even more when major food-crop origins are linked to tropical rainforests to justify their protection. A simple overlay of a map indicating Vavilov centers of diversity--the historic points of origin for almost all major food crops in the world--and a map showing distribution of tropical rainforests indicates significant overlap in only one of nine centers--that of Southeast Asia and Malaysia.

In-situ preservation of biotic diversity through traditional methods of establishment of national parks and protected areas is impossible for some nations to implement for economic and other reasons and will, in general, become less common in the future. Often it is an economic impossibility for some nations to preserve these lands. We are also learning more about the management of ecosystems for multiple benefits (von Droste zu Hulshoff and Gregg, 1985). Allowing limited activity in a given area does not imply the destruction of its potential for advancing science. On the contrary, cultured landscapes can significantly contribute to the maintenance of biotic diversity--especially when it is planned for as a part of development rather than added later as something separate from development.

Sole or heavy emphasis on wildland reserves, especially in the humid tropics, is often incompatible with other development efforts and under restricted budgets may also conflict with the activities of in-situ genetic resource maintenance. Figures of 10 percent of each country to be set aside for "conservation" have been cited as being necessary for adequate genetic resource protection (Gentry, 1984). Table 3 indicates how the countries of Latin America and the Caribbean measure up to this ideal as of 1981. As can be seen, some nations, particularly small countries and island nations, do not have the large undisturbed tracts required for national parks or other wildland reserves and fall far short of the 10 percent figure. Yet they may have valuable genetic resources that have evolved under stress from wind, heat, aridity, salinity, and other specialized conditions.

A further complicating factor is that in many cases, only those lands classified a wastelands--so defined due to their low agricultural production potential or that have been abandoned because of overuse, and erosion--are given for conservation status. Although it is true that the genetic traits of value are often those that have evolved under stress, it would be a costly mistake to forget those species whose habitat is on "good" land. In these cases, justification for in-situ conservation must be very specific and quite explicit. Cooperation and compromise with other development efforts will be necessary and these procedures also need to be emphasized as part of an overall strategy to make them more palatable to decision makers in developing countries. Setting aside wildlands and providing specialized training are difficult routes to take given current socioeconomic conditions.

4. Conflicting Objectives.

Insisting on setting aside large tracts of major biomes on the basis that they are "fragile", "rich", or "key", can easily be interpreted as something other than the best interests of the countries holding those resources. For developing countries, the history of resource use, including the genetic resource, is not encouraging. As a consequence, totally agreement to the maintenance strategies outlined in the many "guidelines" summarized above will not be possible. By and large, the use of natural resources (natural rubber, alpaca, quinine, vencristine, etc.) escape the control of third world countries and the benefits--for many reasons including differences in levels of technology, research facilities, and interest--accrue elsewhere.

The perennial teosinte is an example of the spirit of the disagreement; the significance of the discovery could be "the end of famine" or, "its potential value to the U.S. corn crop of billions of dollars (Vietmeyer, 1979)."

And, according to some, the importance of the issue goes beyond development countries wanting to ensure a return for their plant breeders, and the developing countries wanting to keep their genetic wealth to themselves. Rather, the issue is that this difference "may lead the Third World to deny the First World access to its untapped genetic wealth of wild species and to withhold cooperation in measures to conserve wild genetic resources" (Westoby, 1984:19). Unfortunately, the developing countries where the genetic material of future value often originates have not had much to say in the design of in-situ maintenance strategies; seldom have they equitably participated in their formulation, only under pressure will they participate in their execution and rarely do they share equitably in the profits that may be generated. A notable exception is that of Peru, Bolivia, Chile, and Argentina who have mounted an apparently successful program of vicuña conservation. The program includes important and enforced legislation in all four countries that prohibits the export of fertile animals (Brack, 1980). Since these are the only countries having fertile populations of vicuña, future income will accrue to them and not to others.

5. Institutional Weaknesses and Government Indifference.

Failure of a project or program is common in development planning and, in this regard, it is normal to fault the constraints imposed by lack of sufficient financing. To be sure, budgets for conservation projects are notorious for being small or non-existant. More often than not, however, the major problems, though seldom admitted and rarely understood, are that the funds are misspent; that the recipient does not behave as predicted; that communication and coordination between agencies are insufficient at best and that institutional rivalries may even work against the success of a project. In addition, high turnover rates of professionals and generally insufficient levels of professional training make project completion difficult (Schramm, 1976).

In a recent update of a study by Wetterberg et. al. (1985), lack of trained manpower continued to be a major problem for managing conservation areas in Latin America and the Caribbean. The problem has been studied intensively in the region as well as in Africa since the mid-seventies (Fahrenkrog, 1978; OAS, 1978; WWF, 1980; UNEP, 1982, 1984, 1985). However, neither Governments nor international and bilateral development assistance agencies have elected to come forward with sufficient funding to confront the needs as outlined in these reports.

Despite the numerous meetings calling attention to the importance of biotic diversity to developing countries, the general interest level of the "recipients" appears less than enthusiastic. For example, the Fourth Inter-Governmental Meeting on the Environment in Latin America and the Caribbean, held recently in Mexico to decide on programs of regional and subregional "environmental action" did not mention genetic resource maintenance as an issue (UNEP, 1985b, c).

Lack of cooperation, coordination, and the duplication of effort remain problems both within conservation oriented agencies and between conservation activities and the activities of other agencies that affect conservation areas. Though not alone, the case of Mexico can be cited as an example. Here the administration of National Parks is divided between four different government agencies and their management is delegated to fourteen different national level secretariates (Goebel and Meganck, 1981).

Any country will have a large number of sectoral "decision-makers" scattered throughout the various ministries, departments, and other executing agencies whose rational for any given decision is seldom "economic", rarely fully informed and almost always chauvenistic sectorally (Edmunds, 1984). Decisions are frequently if not always made in favor of a route of minimum conflict with conscience and constituency. The result, more often than not, is then conflict between and among the many private and public agencies hoping to derive some benefit for their own constituencies from the same ecosystem. Conservation of genetic diversity has not as yet reached the level of urgency required for decisions to be made in its favor. Although this fact may be based on how the decision maker views reality, it may also depend on how the concern of conservationists regarding genetic resource maintenance is packaged and sold.

POSITIVE EFFORTS

Fortunately, a number of exceptions exist where local concern, understanding, and effort has grown sufficiently to overcome many of the problems cited above. The first that can be mentioned and which could serve as a model elsewhere is that of INIREB, the Mexican National Research Institute for Biological Resources, which has as its purposes the inventory of plant and animal resources, the study of threatened and endangered species; the establishment of reserves and the protection of habitats of specific ecological importance; the development of alternative land-use strategies; and, the training of professionals in conservation oriented fields (Anon. 1984). Since its founding in 1975, INIREB has prepared formal taxanomic descriptions of 31 plant families and its herbarium, which is open to scientists for study, contains some 95 000 specimens. INIREB, which serves as the Mexican headquarters for the Man and the Biosphere Program, has also been a notable catalytic force for the formation of reserves throughout the country including the famous Montes Azules reserve in the Lacandona rain forest of Chiapas. In addition, the vital role played by INIREB in promoting economically viable land use practices is unique in Latin America and underscores the maturity and balanced programs of this Institute. For example, in the Macuiltianguis Community in Oaxaca, the Community owned an oak-pine forest which was leased to a paper company for extraction. Despite good community organization, the owners received little revenue from their pine lease.

INIREB intervened and assisted the Community in forming a small cooperative tool handle industry to utilize the "waste" of the same forest. This is an example which represents the reality of the Mexican campesino -and an economically viable one which deserves credit and study for the lessons learned and possible adaptation to other areas in the world.

A second noteworthy institution in this regard is that of SEMA, the "environmental" agency of Brazil--especially that portion working with its network of Ecology Stations and Reserves located in areas representative of Brazil's major ecosystems. These stations now cover some 2 103 000 ha and may soon be expanded to cover 3 000 000 ha. Sizes vary from 2 ha to 100 000 ha and are dedicated to ecological research (Nogueira-Neto, 1985).

Two other examples at the local level may be just as important as the above are at the national level. Despite high population densities and intensive land use, the sacred groves of India have existed and have remained essentially undamaged for thousands of years because of religious beliefs (Khoshoo, 1981). Another example is the neo serret, the sacred home of the spirits of the Kuna tribe of Panama. The neo serret are comparatively large tracts of forest kept unaltered because of the religious beliefs of this population (Houseal, et. al., 1985). No doubt there are other similar areas where genetic resources are maintained despite high population pressure.

Two other ideas that are of a positive nature for in-situ maintenance should be mentioned. These are ethnobotany (Barrera, 1979) and restoration ecology (Aber and Jordan, 1985). Ethnobotany is an effort to identify and evaluate the many plant species used by native peoples from their natural habitat. It seems to be a viable way to rapidly evaluate existing genetic resources and their uses and this specialty is now taking its place in development planning (Miller, 1985; Saunier, 1983). Since it is "user" and "now" oriented rather than "future" and "preservationist" oriented, its chances with decision makers are much improved.

Restoration ecology is an attempt to rehabilitate abandoned and degraded lands, the hope being to recreate and maintain former ecosystems. Adequate programs to reclaim abandoned lands at this point are scarce but no less necessary. In Latin America alone, an estimated 10 million ha of forest land are cleared annually for cultivation, for construction materials, and for fuel (World Bank, 1978).

INTEGRATED DEVELOPMENT PLANNING

A model that holds potential for resolution of the many problems facing in-situ maintenance of biotic resources and other conservation issues is that of integrated regional development planning (Saunier, 1983, 1984; OAS, 1984)).

A recently published paper of the IUCN Commission on Ecology (Ricklefs et. al., 1984) supports this concept:

> "The idea of basing conservation on the fate of particular species or even on the maintenance of a natural diversity of species will become even less tenable as the number of threatened species increases and their refuges disappear. Natural areas will have to be designed in conjuntion with the goals of regional development and justified on the basis of ecological processes operating within the entire developed region and not just within natural areas."

Integrated regional development planning is a response to an integrated regional environment where, instead of confronting environmental complexity by subdividing issues into sectoral components, it subdivides the region into smaller spatial units and looks at the sectoral interactions in each. Interactions of this kind are often conflictive for two reasons: (a) competition for the same goods or services by two or more interest groups; or, (b) a change in the mix of available goods and services as a result of the activities of one sector which are detrimental to another sector. In integrated regional development planning these and the interaction with neighboring areas are also analyzed. Consequently, regionalization is necessary and once such regional and subregional environments are defined, connections between neighboring units can be known.

Whereas sectoral development planning (including genetic resource conservation) designs programs and projects to meet the needs of specific target populations, IRDP uses methods of systems analysis and conflict resolution to attempt appropriate distribution of the costs and benefits of development activities throughout the affected populations or sectors. Thus, conflict identification and resolution are fundamental requirements for a development plan to be "integrated." Sectoral integration is necessary because individual sectoral activities may help and often hinder the activities of other sectors in their efforts to appropriate goods and services from the same and allied systems. The decision as to which activities are the correct ones or how each can be adjusted to reduce conflict can only be made through negotiation by the parties involved and not by an individual sector -be it conservation, forestry, agriculture or livestock production- trying to dictate to other sectors.

In this context, integrated regional development planning has a number of advantages over sectoral planning. Conflicts are always easier to resolve before funds and prestige have been invested. Participants in the regional planning exercise, though representing individual interests, have a shared commitment to rules and procedures which can be controlled. Under this model the various parties (sectoral interests) operate with a similar rational and can be easily encouraged to focus on criteria rather than on positions. Further, each can insist that evaluation criteria be objective. This gives an opportunity to invent options that offer mutual gain and minimal conflict. The result is a strategy for development that demonstrates concern for both the target and the affected populations of development projects and programs. And, it includes, where analysis and coordination prove it necessary, conservation of genetic resource as a development activity--as defensible as any other.

TABLE 1

ECOSYSTEM GOODS, SERVICES, AND HAZARDS

1.0 Goods/Products

1. Surface and groundwater for human consumption
2. Surface and groundwater for industry
3. Surface and groundwater for irrigation
4. Biomass for lumber and pulpwood
5. Biomass for firewood
6. Biomass for construction materials from wood (posts, beams, etc.)
7. Vegetation for ornamental plants (indoor, landscaping, dry)
8. Vegetable fibers (rope, cloth)
9. Medicinal plants
10. Food for human consumption (fruits, gum, honey, sap, shoots, seeds, nuts, leaves)
11. Food for human work, animal consumption
12. Food animals for human consumption (fish, fowl, etc.)
13. Aquatic plants for human consumption (algae, sponges)
14. Food condiments (spices, salt, bicarbonate of soda)
15. Plant chemical substances (dyes, stains, waxes, latex, gums, tanning, syrups, drugs, etc.)
16. Fertilizers (minerals, fishmeal, guano, other dung, etc.)
17. Aquatic precious/semiprecious materials (pearl, coral, conchs, mother or pearl)
18. Materials for artisan work (rock, wood for carving, fibres for basketmaking, etc.)

19. Metallic minerals (bauxite, ores, nuggets, etc.)
20. Non-metallic minerals (asbestos, clays, limestone, etc.)
21. Construction materials (sands, clay, cinders, cement, gravel, rocks, marble, etc.)
22. Mineral nutrients (phosphorus)
23. Mineral dyes and glazes
24. Hides, leather, skins
25. Other animal materials (bones, feathers, tusks, teeth, claws, butterflies)
26. Other vegetation materials (seeds, pods)
27. Live fish (ornamental, pets)
28. Live animals for pets and zoos
29. Live animals for human work
30. Live animals for research
31. Fossil fuels (crude oil, natural gas, coal)
32. Other fuels (peat, other organic matter, dung, biomass)
33. Livestock forage

2.0 Ecosystem Operation, Maintenance, Adaptation and Evolution

1. Nutrient cycling
2. Nutrient storage
3. Nutrient distribution (floods, dust, and sediment transport, etc.)
4. Photosynthesis-respiration
5. Adaptation
6. Self-regulation
7. Competition testing and design (population control evolution)
8. Mineral cycling

9. Habitat for local land, air, aquatic animals, insects, and other life forms (feeding, breeding, nursery, shelter, transport, education and training, etc.)

3.0 Non-Tangible Goods and Services

1. Windbrake
2. Shade
3. Recreational use of water (swimming, boating, skating, water skiing, sailing, surfing, scuba)
4. Recreational use of land (hiking, spelunking, climbing)
5. Recreational use of air (flying, gliding, parachuting, flying kites)
6. Recreational use of animals (sport hunting and fishing, insect collecting)
7. Recreational use of ecosystem (sightseeing, tourism)
8. Scientific tourism (exploring)
9. Value development and storage
10. Spiritual development and storage
11. Historical value
12. Cultural value
13. Early warning system (weather and climate change)
14. Moisture modification (humidity)
15. Temperature modification
16. Light modification
17. Ultraviolet and other radiation filtration
18. Storage of life form adaptive (genetic) information
19. Protection of indigenous cultures and customs

4.0 Non-Monetarial Economic Services

1. Energy sources (wind, solar, hydro, tides, biomass, geothermal)
2. Dilution of contaminants
3. Decomposition of contaminants (oxidation, evaporation, dissolution)
4. Transport of contaminants (wind, water, animal consumption, air and watershed dilution of contaminants)
5. Erosion control
6. Sediment control
7. Flood control
8. Groundwater recharge
9. Space for urban, industrial, agriculture occupations, roadways, canals, airports
10. Waste and contaminant storage
11. Physical support for structure
12. Climate control and protection
13. Disease control and protection
14. Storm buffer

5.0 Hazards

1. Diseases and plagues (virus, bacteria, flukes, parasites, fungus, etc.)
2. Natural flooding
3. Avalanches (land, snow, ice), land slips, mudflows, etc.
4. Wind (tornados, hurricanes, cyclones, dust storms)
5. Natural erosion/sedimentation
6. Temperature extremes (duration, intensity)
7. Extremes of humidity (duration, intensity)

8. Drought
9. Snow
10. Ice
11. Hail
12. Fog, mist
13. Frost
14. Solar radiation
15. Lightning
16. Fire
17. Toxic chemicals, gas concentration
18. Nuclear radiation
19. Earthquakes
20. Noxious vegetation (poisonous plants, "invader" species)
21. Poisonous animals (snakes, insects)
22. Predators
23. Volcanoes
24. Tidal waves

SOURCE: Adapted from Saunier, 1981 with revisions by R. Meganck and T. Robertson.

TABLE 2

ALTERNATIVE CATEGORIES FOR THE MANAGEMENT AND DEVELOPMENT OF NATURAL AND CULTURAL RESOURCES TO ACHIEVE PRIMARY CONSERVATION OBJECTIVES

	ALTERNATIVE CATEGORIES FOR THE MANAGEMENT OF WILDLANDS												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
Primary Conservation Objectives	National Park	Natural Monument	Biological or Scientific Reserve	Wildlife Sanctuary or Refuge	Resource Reserve	National Forest	Wildlife Utilization Area	National Recreation Area	Cultural Monument	National River	Parkways	Protection Areas	Easement or Limited Use Areas
To conserve sample ecosystems in a natural state	1	1	1	3	3	3	3	3	3	1	2	3	3
Conserve ecological diversity, environmental regulation	1	1	1	1	1	1	2	2	3	1	2	2	2
Conserve genetic resources	1	1	1	1	3	3	3	4	4	3	4	4	4
Provide education, research, and environmental study areas	1	1	1	1		2		2	1	1	2		
Conserve hydrological production	2	3	2	2		1	2	2	3	1	3	1	3
Control erosion, sedimentation and protect downstream works	2	3	2	2		1	2	2	3	1	3	1	3
Produce fauna protein, hunting and sport fishing						1	1	3		3			
Provide recreation and tourism services	1	2		3	1	3	1	2	1	1		2	
Produce wood and forage on a sustained yield basis						1						3	
Protect sites and objects of cultural, historic, and archaeological significance	1	3				2		3	1	3	1		
Protect and conserve scenic beauty and green areas	1	1		2		2	2	1	2	1	1	2	1
Maintain open options, flexibility of management and multiple use					1	1							
Encourage rational use of marginal lands and integral development	2	2		2		1	1	2	3	2	2	2	2

1. Primary objective for the management of the areas and its resources.

2. Not necessarily primary, but always included as an important objective.

3. Included as an objective where the resources and other management objectives so permit.

SOURCE: Thelen K.D.; Miller, K.R. 1976. Planificación de Sistemas de Areas Silvestres. Doc. No. 16. FAO/ORLAT/TF. Corporación Nacional Forestal. Pp 199. Santiago, Chile.

TABLE 3

NATIONAL PARKS AND OTHER PROTECTED AREAS IN THE LATIN AMERICAN REGION (1981)

Country	Total Area (km2)	Percentage of Protected Areas (%)
Antigua & Barbuda	440	5.68
Argentina	2 766 889	1.28
Bahamas	13 935	8.73
Barbados	431	0.58
Bolivia	1 098 581	4.26
Brazil	8 511 965	1.70
British Virgin Is.	2 173	0.42
Chile	756 945	11.14
Colombia	1 138 914	3.45
Costa Rica	50 000	10.79
Cuba	114 524	0.21
Dominica	751	9.10
Dominican Republic	48 734	3.02
Ecuador	283 561	9.27
El Salvador	21 393	0.09
Guatemala	108 889	1.54
Guyana	214 969	0.05
Haiti	27 750	0.009
Honduras	112 088	3.19
Jamaica	10 962	0.03
Martinique	1 100	0.36
Mexico	1 972 546	0.30
Netherlands Antilles	992	13.56
Nicaragua	130 000	0.13
Panama	75 650	11.37
Paraguay	406 752	3.03
Peru	1 285 216	5.28
Puerto Rico	8 897	0.07
Suriname	163 165	3.56
Trinidad & Tobago	5 130	4.68
US Virgin Islands	345	21.59
Uruguay	176 215	0.11
Venezuela	912 050	8.09

SOURCE: Adapted from UN/JIU/REP (1982).

BIBLIOGRAPHY

Aber, J.D. and W.R. Jordan III. 1985. Restoration Ecology: An Environmental Middle Ground. BioScience, 35, (7).

Anon. 1981. Save the Tai Forest. IUCN Bulletin. New Series Vol. 12, No. 3-4. pp 10-11.

Anon. 1984. Visión Holística del INIREB en la Conservación de la Naturaleza. INFORPALC/UNEP-México. November.

Anon. 1985. Threats to the Chatateau d'Eau in Rwanda. World Conservation Strategies in Action. March. 1985.

Barrera, A. 1979. La Etnobotánica: Tres Puntos de Vista y una Perspectiva. Instituto de Investigaciones sobre Recursos Bióticos A.C. Xalapa. pp 29.

Barriga, E. and A.M. Byers. 1982. Conservation in Latin America: A Look at Two Countries. The Nature Conservancy News. Vol. 32, No. 4. pp 16-22.

Brack, A. 1980. Conservación de la Vicuña en el Perú. Proyecto Especial Utilización Racional de la Vicuña. Ministerio de Agricultura y Alimenticia. Lima, Perú.

Burley, F.W. 1982. Sharing the Heritage Concept. The Nature Conservancy News. July-August. pp 23-25.

Daugherty, H. 1972. The Montecristo Cloud Forest of El Salvador -A Chance for Protection. Biological Conservation 5 (3): 227-230.

Eckholm, E.P. 1978. Wild Species vs. Man: The Losing Struggle for Survival. Living Wilderness, 42 (142): 10-22.

Edmunds, S.H. 1984. Strengthening Development Administration. Managing International Development. 1 (2).

Fahrenkrog, E. 1978. Final Report: Study for the Establishment of an Inter-American Training Center for Management and Operations Personnel of National Parks and Similar Areas. World Wildlife Fund. U.S. Washington, D.C.

FAO. 1979. Declaration of the Eighth World Forestry Congress. Djakarta, Indonesia.

Gentry, A. 1984. Potential Useful Plant Resources of the Eastern Andes. USAID/Missouri Botanical Gardens, Contract No. DAN- 5542-G-55-1086-00. Washington, D.C.

Goebel, J.M. and R.A. Meganck. 1981. Mexico's National Park: An Update and Management Problem Analysis. In Woodpower: New Perspectives on Forest Usage. Ed. J.J. Talbot and W. Swanson. Pergamon Press.

Goulet, D. 1971. The Cruel Choice. Atheneum, New York. pp 362.

Hahn, C. 1984. Environment and Development: Balancing both Worlds. Horizons.

Hanson, A.J. and Koesoebiono. 1977. Settling Coastal Swampland in Sumatra: A Case Study for Integrated Resource Management. Center for Natural Resource Management and Environmental Studies. Bogor Agricultural University. Indonesia.

Harrison, J., K. Miller, and J. McNeely. 1982. The World Coverage of Protected Areas: Development Goals and Environmental Needs. Ambio, 11 (5): 238-245.

Holdgate, M.W., Kassas, M. and G.F. White. 1982. World Environmental Trends Between 1972 and 1982. Environmental Conservation. Vol. 9, No. 1. pp 11-29.

Houseal, B., MacFarland C., Archibold, G., and A. Chiari. 1985. Indigenous Cultures and Protected Areas of Central America. Cultural Survival. March, 1985.

Hufschmidt, M.M., D.E. James, A.D. Meister, B.T. Bower, and J.A. Dixon. 1983. Environment, Natural Systems, and Development. The Johns' Hopkins University Press. Baltimore, MD. pp 338.

INTER-PARLIMENTARY UNION. 1985. Conclusions and Recommendations on the Conference on The Environment 1984, No. 1, Nairobi.

Iltis, H., Doebley, J., Guzman, R., and B. Pazy. 1979. Zea diploperennis (Graminease): A New Teosinte from Mexico. Science, Vol. 203.

IUCN. 1982. The United Nations List of National Parks and Protected Areas. Gland, Switzerland.

Khoshoo, T.N. 1981. Conservation of Biological Diversity: The Indian Experience. In: Proceedings of the U.S. Strategy Conference on Biological Diversity. November 16-18, 1981. Washington, D.C.

Kishk, M.A. and C.R. Bailey. 1985. Technical and Human Aspects in Desert Agricultural Development in Egypt: Constraints and Prospects. In. Arid Lands. Today and Tomorrow. An Arid Lands Research and Development Conference. Tucson, Arizona. October 1985.

Krutilla, J.V. and A.C. Fisher. 1975. The Economics of Natural Environments. Resources for the Future. Johns' Hopkins University Press. Baltimore, MD. pp 292.

Lovejoy, T. 1979. The Conservation of Evolution. Parks, Vol. 4, No. 2. Washington, D.C.

Lugo, A.E., Ralph Schmidt and Sandra Brown. 1981. Tropical Forests in the Caribbean. AMBIO. 10(6). pp 318-324. Pergamon Press, New York.

McHale, J. and M.C. McHale. 1977. Basic Human Needs: A Framework for Action. New Brunswick, NJ.

Meganck, R.A. 1975. Colombia's National Parks: An Analysis of Management Problems and Perceived Values. PhD Dissertation, Oregon State University. Dissertation International No. 75-26-062, 32 (5). Ann Arbor, Michigan.

Meganck, R.A. and R.E. Saunier. 1983. Managing our Natural Resources.; Caribbean Naturalist. 4 (8), Port of Spain. pp 11.

Miller, K.R. 1985. Closing the Credibility Gap. IUCN Bulletin. 16 (1-3).

Monfort, A. and N. Monfort. 1984. Akagera: Rwanda's Largest National Park. Parks, Vol. 8, No. 4, pp 6-8.

Myers, N. 1984. A Wealth of Wild Species. Westview Press. Boulder, Colorado. pp 274.

Nicholls, C.F. 1985. Forestry in St. Vincent and the Grenadines. In Watershed Management in the Caribbean. Ed. A.E. Lugo and S. Brown. Institute of Tropical Forestry. USFS.

Nicholson, M. 1984. Threatened Protected Areas of the World. IUCN Bulletin, 15 (7-9).

Nogueira-Neto, P. 1985. Getting Brazil's Network of Ecological Station on the Ground. Journal'85. World Resources Institute. pp 27-34.

OAS. 1978. Final Report: Technical Meeting on Education and Training for the Administration of National Parks, Wildlife Reserves and Other Protected Areas. Regional Scientific Technological Development Program. OAS. September 25-29, 1978. Mérida, Venezuela.

OAS. 1984. Integrated Regional Development Planning: Guidelines and Case Studies from OAS Experience. OAS General Secretariat, Washington, D.C.

Oldfield, M.L. 1984. The Value of Conserving Genetic Resources. U.S. Department of the Interior, Washington, D.C. pp 360.

Prescott-Allen, R. and C. Prescott-Allen. 1985. Park Your Genes: Wild Genetic Resources and Protected Areas. IUCN Bulletin. Vol. 16 (1-3). pp 17-18.

Ricklefs, R.E., Z. Naveh, and R.E. Turner. 1984. Conservation of Ecological Processes. The Environmentalist, 4 (8).

Robinson, A.H. and Y. Rustandi. 1982. Bali Barat National Park. Parks, Vol. 7, No. 2. pp 13-14.

Saunier, R.E. 1984. Regional Approaches Utilized in Development Planning. Natural Resource Technical Bulletin. No. 5. AID-NPS Natural Resources Project.

Saunier, R.E. 1983. Environment and Development ... A Future Together? Development Forum. 11 (8).

Saunier, R.E. 1981. Unidades Ambientales. In: Planificación de las Cuencas de los Ríos Napo y San Miguel. Pub. No. 8. DP/RM. 81. Consejo Nacional de Desarrollo, Instituto Ecuatoriano de Recursos Hidráulicos. Organización de los Estados Americanos.

Saunier, R.E. 1979. An Environmental Perspective for Development Planning Missions in the Field. UNDP/IIED Seminar on the Environment. January, 1979, New York.

Schramm, G. 1976. Human-Institutional Factors. Natural Resources Journal. Vol. 16. October. The University of New Mexico, School of Law.

Sierra Club. 1981. World Environment Report. March. pp 2.

Tolba, M. 1982. Development without Destruction. Tycooly International. Dublin.

Thelen, K.D. and K.R. Miller. 1976. Planificación de Sistemas de Areas Silvestres. Doc. No. 16. FAO/RLAT/TF 199. Corporación Nacional Forestal. Santiago, Chile. pp 63.

Udvardy, M.D.F. 1975. A Classification of the Biogeographical Provinces of the World. IUCN Occasional Paper No. 18. Morges, Switzerland. pp 48.

Udvardy~~, M.D.F.~~ 1984. A Biogeographical Classification System for Terrestrial Environments. In: McNeely and Miller. National Parks, Conservation and Development. Smithsonian Institution Press. pp 34-38.

UNEP. 1985a. Population and the Environment. In The State of the Environment. 1985.

UNEP. 1985b. Aportes para una Evaluación de los Asuntos Ambientales en América Latina y el Caribe: Tendencias, Enfoques y Perspectivas al Año 2000. IV Reunión Regional Intergubernamental sobre Medio Ambiente en América Latina y el Caribe. Cancún, México. April 18-20. UNEP/I.G. 57/3.

UNEP. 1985c. Final Report. Fourth Inter-Governmental Regional Meeting on the Environment in Latin America and the Caribbean. Cancún, México. UNEP/I.G. 57/8.

UNEP. 1984. Red Regional de Instituciones para la Formación Ambiental. Informe de Actividades de 1982-1983 y Sugerencias de Programación para 1984. UNEP/I.G. 47/4.

UNEP. 1983. Projet de Programme d'Action pour l'Education et la Formation en Matiere d'Environnement en Afrique. UNEP/W.G. 87/2.

UNEP. 1980. Genetic Resources: An Overview. United Nations Environment Programme. No. 5. Nairobi, Kenya.

UN/JIU/REP. 1982. Contribution of the United Nations System to the Conservation and Management of Latin American Cultural and Natural Heritage. Report of the U.N. Joint Inspection Unit. Geneva.

U.S. Department of State. 1982. Proceedings on the Conference on Biological Diversity. Department of State Publication 9262. Washington, D.C. pp 126.

Vietmeyer, N.D. 1979. A Wild Relative May Give Corn Perennial Genes, Smithsonian. pp 68-76.

Vogt, W. 1946. Mexico's National Parks. National Parks Magazine. April-June. pp 13-16.

von Droste zu Hulshoff, B., and W.P. Gregg. 1985. Biosphere Reserves: Demonstrating the Value of Conservation in Sustaining Society. Parks Vol. 10, No. 3. pp 2-5.

Weber, B. 1985. Le Parc National des Volcans Biosphere Reserve: Cooperation between Conservation and Development. Parks Vol. 10, No. 3. pp 19-21.

Westoby, J. 1984. Genetic Erosion. IUCN Bulletin. January-March. pp 18.

Wetterberg, G.B. and R.A. Meganck. 1978. Colombian National Parks and Related Reserves: Research Needs and Management. In: International Experience with National Parks and Related Reserves, Department of Geography. Publication Series No. 12, University of Waterloo.

Wetterberg, G.B., M.T. Jorge Padua, A.T. Bernardes Quintao, and C.F. Ponce del Prado. 1985. Decade of Progress for South American National Parks. 1974-84. National Park Service, U.S. Department of the Interior, Washington, D.C. pp 125.

World Bank. 1978. Forestry Sector Policy Paper. Washington, D.C.

WRI. 1984. Biological Diversity Working Group --Recommendations for a United States Strategy to Conserve Biological Diversity in Developing Countries. Washington, D.C. pp 83.

WRI. 1985. Progress in the Conservation of Biological Diversity. WRI Journal. pp 7-10.

WWF. 1980. Strategy for Training in Natural Resources and Environment. U.S. Washington, D.C.

Contract Paper No. 6

The Role of Development Assistance in Maintaining Biological Diversity In-Situ in Developing Countries

Bruce Rich and Stephen Schwartzman
Environmental Defense Fund

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THE ROLE OF DEVELOPMENT ASSISTANCE IN MAINTAINING BIOLOGICAL DIVERSITY IN-SITU IN DEVELOPING COUNTRIES

By Bruce Rich And Stephan Schwartzman

Natural Resources Defense Council

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ABSTRACT

This paper describes the role of development assistance in preserving in situ biological diversity in developing countries. Section one discusses general US interests in preserving in situ biological diversity in economic, scientific, and moral terms. It then gives an overview of US legislation pertaining to biological diversity, concluding with a discussion of the US Strategy on Conservation of Biological Diversity and offers recommendations for the strengthening of this strategy.

The paper then discusses the activities of US government agencies in preserving biological diversity in the developing world, including USAID, the Department of State, the Fish and Wildlife Service and National Park Service of the Department of the Interior, the USDA's US Forest Service, the Peace Corps and the Inter-American Foundation. The major constraints noted are that US agencies with technical expertise in conservation have limited mandates to act internationally and are relatively uninvolved in development assistance. The major opportunities are for these agencies to work more closely with USAID, and for more attention to be given to innovative small projects like those of the IAF that depend on and stimulate local initiatives in sustainable development in the Third World.

The role of the multilateral banks, as the largest providers of development assistance, is treated in detail. Their role in setting aside protected areas, their environmental policies, and types of projects funded by the MDBs that contribute to habitat destruction are analyzed, and alternatives to these projects are discussed. The MDBs emerge as uniquely situated to influence development policy (for better or for worse) in the developing countries, and to incorporate conservation and in situ preservation of biological diversity into development projects. Recomendations include use of appropriate technolgies, greater involvement of local peoples in planning and environmental protection, and halting the funding of environmentally destructive projects. A major constraint on MDB action to preserve in situ biological diversity is their lack of policies on conserving biological diversity as such.

Various private voluntary organizations and nongovernmental organizations are described. While PVOs typically do not do conservation projects or establish protected areas, their work is seen as important to the preservation of biolgocial diversity since they focus on community level projects directed at the poverty and resource degradation that result in habitat destruction. NGOs working with indigenous groups can contribute to the protection of habitat and to the preservation of expert knowledge of little known species by helping indigenous groups press land claims. The importance of the World Wildlife Fund and the International Union for the Conservation of Nature and

Natural Resources, as the largest conservation organizations in the world, is noted.

Major categories of research institutions are described, and recommendations are offered for research on the improved valuation of environmental costs and benefits in development planning.

Suggestions for increased private sector action on biological diversity are also made, although the paper concludes that market forces alone are unlikely to have much positive effect on conserving in situ biologcial diversity.

I. US Interests in Preserving in situ Biological Diversity in Developing Countries

The most biologically diverse, species-rich ecosystems in the world--tropical moist forests, coral reefs and mangrove wetlands--are located in the developing world. These areas are being rapidly disrupted or destroyed, leading to massive extinction of plant and animal species. In many areas the rate of habitat destruction is increasing exponentially. (Fearnside 1982) Two thirds of all species occur in the tropics, and more than two-fifths of all species occur in tropical moist forests. Scientists estimate that 15-20% of existing plant and animal species may become extinct by the year 2000, largely from deforestation, pollution and overexploitation. (Meyers 1984a, 1984b, IUCN 1980) This would involve the irreversible loss of 500,000 to 1 million species. One of ten plants is extinct or endangered; some 20,000 species are known to require protection. (NAS 1975) A growing body of scientific evidence shows that US interests would be best served by preventing or minimizing this ongoing process of extinction. (Myers 1979; Ehrlich and Ehrlich 1981; Eckholm 1978; NAS 1978; NAS 1980a; NAS 1980b)

The importance of in situ biological diversity to US interests can be considered in economic, scientific, and moral or humanitarian terms.

In situ biological diversity is the natural underpinning of the genetic variability indispensible to modern agriculture and livestock breeding. Manipulation of genetic diversity has permitted increased yeilds, resistance to diseases and pests, and improved quality in crops and domestic animals. Modern monocrop agriculture is a result of extensive cross-breeding, but the few genetically uniform moncrops on which world food production now depends are highly vulnerable to disasterous failure caused by pests and pathogens. The Southern Leaf Blight outbreak of 1970 (which resulted in approximately $1 billion loss), and the Phylloxera plant lice attack that devastated European wine production in the second half of the 19th century are examples. In both cases the use of resistant cultivars averted economic disaster. (Oldfield 1984) Germplasm banks and other ex situ techniques for preserving genetic diversity are invaluable to viable agriculture worldwide, but in the long run are no substitute for maintaining natural diversity in the world gene centers. Pests and pathogens are flexible and overcome resistance, and soil and climate conditions vary or may change. Diverse crop strains from the world gene centers have developed their characteristics in response to often poorly understood evolutionary pressures over millions of years, and reducing their numbers reduces the scope of adaptation, halting or diminishing the process by which valuable new strains or traits are produced. (IUCN 1980)

Only 20 plant species account for 80% of human food consumption, and some 3,000 plants out 240,000 estimated plant species have been used for food. But 80% of the world's plant and animal species remain to be named, such that the potential for discovery of useful new food species is very great. (Myers 1984; NAS 1980; NAS 1975)

The medical uses of plants and animals are also of great economic importance. 40% of US prescriptions in 1973 contained active ingredients derived from plants or animals, and 25% contained ingredients derived from higher plants. In 1980 these last alone had an estimated retail value of over $4 billion. (Oldfield 1984) The demand for drugs that use or are modeled on naturally derived active ingredients is unlikely to decrease. Diseases become resistant to drugs and new ones must be found. New drugs derived from tropical forest species and marine biota have had success in treating a variety of diseases including some forms of cancer. Since most of these species still remain unidentified or unstudied, their medical and pharmaceutical potential is very great. (NAS 1975; Myers 1984)

Scientific interest in _in situ_ biological diversity arises from the fact that areas such as tropical forests provide unparalleled opportunities to understand complex processes of evolutionary interaction. If the world's threatened centers of biological diversity are not protected, the raw materials for new technologies, such as genetic engineering, will be drastically diminshed.

Conservation of habitat areas also provides a series of free environmental services known to be of economic value. These include watershed protection, protection against erosion, micro-climatic stabilization, flood control, protection of fisheries, natural processing of pollutants, and others. (Goodland 1979, 1980)

Preservation of biological diversity is also a moral question. A huge and extremely rapid reduction of the world gene pool is underway, which if unchecked would leave our descendants one or two generations away in a biologically poorer world than ours. Species extinction is irreversible--we can destroy species but cannot create them. Given the importance of biological diversity to sustaining life, and the irreversible nature of extinction, the present reduction in biological diversity in effect robs future generations of free and widely distriubted goods for the presumed benefit of this generation.

II. U.S. Legislation and In Situ Biological Diversity

The need for US action to preserve biological diversity was recognized in Section 119 of the Foreign Assistance Act, added by the Congress as part of the International Environmental Protection Act of 1983. Part (a) states, "The Congress...finds that the extinction of animal and plant species is an irreparable loss with potentially serious environmental and economic consequences for developing and developed countries alike," and further designates the preservation of animal and plant species an "important objective of the United States development assistance." (Committee on Foreign Affairs, 1984) Part (b) authorizes assistance for "protecting and maintaining wildlife habitats and in developing sound wildlife management and plant conservation programs," specifically in order to preserve biological diversity. Part (c) mandates a US strategy, to be elaborated by USAID and other agencies, for preserving biological diversity. Part (d) calls for a report to Congress on the US strategy to protect biological diversity.

This legislation follows a patten of increasing Congressional concern with international environmental protection. President Carter's Executive Order 12114, "Environmental Effects Abroad of Major Federal Actions", of February 4,1979, established internal procedures for Federal agencies concerning the environmental effects of their actions abroad, and required stipulated agencies to issue regulations to implement its directives. Federal agencies were to prepare Environmental Impact Statements for actions resulting in "significant environmental effects" on the global commons (eg, the oceans and atmosphere). Agencies were also required to prepare "environmental reviews" for actions involving regulated toxic substances, or affecting a third nation, or for actions affecting natural resources of global importance as designated by the President or by international agreement. (Executive Order 12114, February 4, 1979). The US Agency for International Development complied with the order by adopting mandatory environmental assessment regulations for categories of envrionmentally significant development projects, including river basins, irrigation and dams, power projects, resettlement, roads and agricultural mechanization schemes. (Blake et al, 1980) The Overseas Private Investment Corporation (OPIC) and the Export-Import Bank also promulgated environmental review regulations to comply with Executive Order 12114.

US Foreign Assistance did not have a specific legislative mandate to incorporate environmental concerns in its activities until the late 1970s, when a series of ammendments to the Foreign Assistance Act defined USAID's mandate in the area of environment and natural resources. These amendments gave special emphasis to promoting efforts to halt tropical deforestation, and thus also to conserve in situ biological diversity. In 1977, Section 102 of the Act was amended, adding environment and natural resources to areas of development AID should address. The same year, a new Section, 118, was added to the Foreign Assistance Act, on "Environment and Natural Resources", authorizing AID to fortify "the capacity of less developed countries to protect and manage their environment and natural resources" and to "maintain and where possible restore the land, vegetation, water, wildlife, and other resources upon which depend economic growth and well-being, especially that of the poor," (Committee on Foreign Affairs 1983). In 1978 Section 118 was amended requiring AID to carry out country studies in the developing world to identify natural resource problems and institutional mechanisms to solve them. (Ibid.) In 1978 and 79 Congress amended Section 103 of the Foreign Assistance Act to emphasize forestry assistance, acknowledging that deforestation (with its attendant species loss) constituted an impediment to meeting basic human needs in developing countries.

Section 118 was amended again in 1981, making AID's environmental review regulations part of the Act, and a subsection (d) was also added, characterizing tropical deforestation as "a serious threat to development and environment in developing countries." Referring to Section 103 of the Foreign Assistance Act, subsection (d) states, "The Congress is particularly concerned about the continuing and accelerating alteration, destruction and loss of tropical forests in developing countries." (Committee on Foreign Affairs 1983) It further instructs the President to take these concerns into account in formulating policies and programs relating to bilateral and multilateral assistance and private sector activities in the developing world. (Ibid.) The recommendations of the Interagency Task Force on Tropical Forests are also to be considered by the executive branch in carrying out and coordinating development policies and projects as well as private sector activities affecting tropical forests.

The Inter-Agency Task Force on Tropical Forests emerged from a Strategy Conference held in 1978 by USAID and the State Department on tropical deforestation. In May of 1980 the Task Force issued a detailed Tropical Forest Strategy for US foreign assistance and research programs. Congressional interest in deforestation also resulted in two hearings on the subject before the House Foreign Affairs Committee in May 1980 and September 1982.

The Task Force set short, middle, and long-term goals for US policy. Short-term goals (1-5 years) included obtaining policy commitments from tropical forest countries and international organizations for an international program to introduce low-cost energy and alternative food production systems in rural areas, and for improved long-term forest management practices. A middle-term goal essential to the preservation of biological diversity in tropical forests is the formulation of action programs by individual countries to preserve and study representative and unique forest ecosystems as well as indigenous cultivation systems associated with them. The long term goal, a stabilized global ecological situation, was held by the Task Force to depend on international cooperation in slowing population growth, and in producing food, shelter, and energy for the world's poor. (US Department of State 1980)

The most concrete result of amendments to AID's environmental mandate was that AID has greatly increased its activities in the forestry sector, establishing a Forestry Support Program and increasing lending in this sector more than tenfold from 1977 to 1982.

The addition of a biological diversity amendment--Section 119--to the Foreign Assitance Act in 1983, then, follows nearly a decade of increasing legislative and Administration concern for the role of US foreign assistance in conserving the international environment.

Official U.S. Government interest in biological diversity dates from 1981, when the U.S. Strategy Conference on Biological Diversity was held under the auspices of the U.S. State Department. The conference included some three hundred participants from the Government, the Congress, university and business communities and national and international nongovernmental organizations. Conference participants emphasized the urgency of measures to preserve genetic diversity, *in situ* and *ex situ*, and agreed that tropical forests and coastal areas, which are highly diverse and undergoing rapid transformation, are priorities for study and preservation. (Department of State 1982) Conferees also agreed that environmental pressures such as pollution, overpopulation, and extreme poverty will probably result in large scale species extinction within the next 30-40 years, and that priorities must therefore be set for conservation and preservation of species.

One recommendation of the conference was that an Interagency Task Force on Biological Diversity be created to review U.S. policy and programs and suggest long term U.S. goals in the area, and that it report to the President by 1983. (This Task Force was finally created, in fact, only in response to an explicit directive of the 1983 biological diversity amendment to the Foreign Assistance Act, Section 119.) Following the lead of IUCN's World Conservation Strategy, the conferees also recommended that conservation, including protected areas, be included in development planning. They further suggested that traditional uses of plant and animal resources by indigenous peoples be studied as a means of developing sustainable resource use systems. The U.S. was encouraged to cooperate with international organizations addressing the problem of species loss, such as UNEP, FAO, UNESCO's Man in the Biosphere Program (MAB), and NGOs such as IUCN and WWF. While the conference concluded that both in situ and ex situ preservation should be pursued by all countries, the recommendations focused more on the need for improved training and inventories, free exchange of genetic material and information, and research on species loss and distribution and the effects of conversion and pollution on wildlands than on conservation measures as such. Nonetheless, recommendation No. 2 states, "The United States should support efforts to identify, establish, and manage a worldwide system of conservation areas representing the major ecosystem types, particularly those which are unique, fragile, and/or highly diverse." (Department of State, 1982) The Ecosystem Management Panel also called for incorporating "the objectives of maintaining biological diversity into technical and financial assistance projects at the international level," (Ibid.) as well as suggesting that the U.S. "provide assistance to developing countries to expand the network of protected areas to maintain biological diversity."

Although the Strategy Conference on Biological Diversity was held in 1981, it was only in response to specific legislative requirements in the International Environmental Protection Act of 1983 that AID and other agencies proposed a U.S. response to problems of biolgical diversity. This was in the form of two reports: the "Wildlife Resources Report," prepared by the Department of State and USAID and published in December of 1984, and the U.S. Strategy on the Conservation of Biological Diversity, released in February, 1985. Both reports drew on the work of the U.S. Biological Diversity Strategy Conference, and were the subject a hearing in June, 1985 before the Subcommittee on Human Rights and International Organizations of the House Foreign Affairs Committee. Since the Strategy was intended by Congress to be the blueprint for U.S. action on biological diversity in the developing world, we will discuss it in some detail.

III. The US Strategy on Conservation of Biological Diversity

While the US Strategy on the Conservation of Biological Diversity and the State and Interior Department's "Conserving International Wildlife Resources: The United States Response" both contain useful recommendations and summaries of what US institutions are doing in these areas, neither shows any commitment to action. In this regard, they represent an inadequate response to Congress's mandate. In requiring high level Executive branch officials to prepare a strategy over a year long period, Congress clearly expected that US objectives would be identifed and methods to achieve them specified. Instead the Strategy contains only a list of recommended actions, qualified by such disclaimers as:

> The Task Force recognizes that decisions on the implementation of the various recommendations will be made on a case-by-case basis by the US Government agencies and other organizations identified in the text. In making these decisions, each organization will consider the relative merits of biological diversity considerations vis-a-vis other competing priorities within its own programs. These decisions must take into account current US federal budget stringencies which will require some program reductions and thus limit the number of new program starts. (USAID 1985)

Budget constraints undoubtedly limit the degree to which US agencies represented on the task force can take effective action to limit or halt the destruction of biological diversity. It is therefore all the more urgent for USAID and other agencies on the Task Force to set clear priorities and indicate which actions they are to take and how much they will cost. The Wildlife Resources Report does suggest "options" that would require increased funding, with cost estimates, but neither document commits US agencies even to actions that would require no additional resources. The utility of the recommendations is severely limited in the absence of a plan for which of them are to be implemented, when, and at what cost. With this response, the Executive Branch has in effect told Congress that it does not believe the conservation of biological diversity deserves priority attention. If Congress wants substantive actions, it must enact legislation that requires them.

The recommendations of the Strategy will not be repeated here. The Wildlife Resources Report contains certain recommendations not found in the Strategy, in particular those for an interagency coordination mechanism (3.1) and actions to influence multilateral development banks (5.4). (Department of State 1984) With respect to the Strategy, which should have been the more comprehensive of the two documents, there are a number of key points omitted that would greatly enhance US efforts to preserve biological diversity. These include:

-- Discussion of the additional funding necessary and recommendations that specified amounts be spent to help developing nations manage wildlife and establish and maintain protected areas. The US, as the wealthiest nation on earth cannot credibly ask developing nations faced with extreme poverty, hunger, international debt and, in many cases, multilaterally imposed austerity measures, to take conservation measures unless it offers concrete incentives and shows some willingness to help defray the costs. Given the great pressures on tropical forests, wetlands, and other such areas in the developing world, establishing protected areas is the only way to preserve _in situ_ biological diversity. In this light, failure to discuss U.S. resources to be committed is perhaps the most serious failing of the Strategy.

-- Recognition of the central role played by IUCN and WWF and recommendations that US agencies place a high priority on establishing close relationships with them. IUCN and WWF have done groundbreaking work in identifying and researching conservation needs worldwide, and have an extensive network of conservation experts worldwide. Their influence and expertise should be used by US agencies in promoting the preservation of biological diversity.

--Endorsing the World Conservation Strategy as an overall guide for preservation of biological diversity in the developing world. This Strategy has been endorsed by numerous nations and offers a model for US action that places preservation of biological diversity in the center of conservation and development concerns in general.

--Recommending that the US act systematically to influence the multilateral development banks in favor of conservation and undertake a study of the impacts on environment and biological diversity of the International Monetary Fund. Since the influence of multilateral banks on the key areas of agricultural and land use policy is unparalleled, this point is of particular importance. No attempt at slowing species extinction can hope to succeed without working in conjunction with development planning, since the most serious pressure on habitats results in the first instance from poverty. The multilateral banks are thus uniquely situated to promote the preservation of biological diversity in the developing countries.

--Recommending that US AID establish a small central fund to make it possible to support global and regional biological diversity initiatives.

--Recommending that AID set up better mechanisms and place higher priority on support for indigenous NGOs in developing countries and spend specified amounts in this way. NGOs are often directly linked to local communities and can carry out more effective environmental education, organizing,and conservation oriented projects than large international organizations. (see pp 30; 52, below) Increased support for such groups would result in greater support for preserving biological diversity in the developing world.

-- Recognition that conservation of biological diversity in developing nations depends in the long run on success in acheiving sustainable development, and that this is unlikely unless the US provides more assistance. Only sustainable use of natural resources will in the long run remove pressure from habitats now being destroyed. In most developing countries this goal is distant and will require extensive foreign assistance.

IV. US Agencies and In Situ Biological Diversity

Various sources describe US activities in this area, including the US Strategy on Biological Diversity, Conserving Internationl Wildlife Resources: The United States Response, Sustaining Tropical Forest Resources--US and International Institutions (a background paper of the OTA), and the State Department'sUS Activites Related to [In Situ] Conservation of Endangered Animal and Plant Genetic Resources. Activities described in the areas of research, inventories, resource management and conservation training, and implementing international agreements such as CITES, are useful and necessary measures. Since much more could be done, we will concentrate on ways that the US effort could be enhanced, noting major constraints and opportunities.

A. US Agency for International Development (USAID)

USAID received a clear mandate from Congress to act on biological diversity in subsection (b) of Section 119 of the Foreign Assistance Act. (Committee on Foreign Affairs 1983) Since AID was also the first development aid agency to receive a direct conservation mandate, it has the opportunity to play a leadership role and to influence the exependiture of much larger sums of money by other aid agencies, including the multilalteral development banks. In fact AID had already begun many of the steps mandated by Congress before the legislation was written. A further opportunity for AID is that a well-organized worldwide network focused on biological diversity already exists, centered on IUCN and WWF. These organizations have developed the highly influential World Conservation Strategy, and AID's ongoing collaboration with them is a step in the right direction. In their ongoing conservation work IUCN and WWF and have identified biological diversity priorities all over the world.

AID already supports a number of ongoing projects involving conservation. These include the preparation of a National Conservation Strategy in Nepal; various other country National Conservation Strategies and Country Environmental Profiles; training programs in integrated ntural resources management carried out by the US National Park Service in Mahidol University in Thailand and the University of Zimbabwe; the Mahaweli Environment project in Sri Lanka, which includes parks and reserves to protect wildlife and habitat and strengthening the Sri Lankan Park and Wildlife Department; and the Bururi Forest project in Burundi, to preserve a rare high-altitude forest. In the FY 1986 Congressional Presentation, Biological Diversity is listed as a new research module in the Office of the Science Advisor's research priorities. There is also, under Agriculture, Rural Development, and Nutrition, a "Natural Resources Research and Training" program, described as aiming to "improve knowledge of effective natural resource management techniques", and which includes "social and ethnographic aspects of traditional land use." This program has potential to collect valuable, little known information on uses and management of tropical species. AID's adoption of a new policy on moist tropical forests in 1984 was also an important step, and its work on forestry, especially fuelwood, is also relevant to the preservation of biological diversity.

The Forestry Support Program, established in conjunction with the U.S. Forest Service, is an important step in using the technical expertise of US agencies with conservation experience to improve environmental aspects of AID programs. This cooperative venture could be expanded to focus more directly on in situ conservation of biological diversity. The Forestry Support Program is already directed to work with AID on conservation issues, and has a registry of some 2,200 foresters and soil and water conservation professionals. Use of FSP's resources and expertise in training and education of planners and managers in developing countries to specifically focus on preservation of biological diversity is a significant opportunity for AID to enhance its imapct in this area.

Given that the pressures resulting in habitat destruction are so widespread and complex, including poverty, overpopulation, pollution, and unsound agricultural policy, a great variety of programs can be construed as contributing to the preservation of biological diversity. In a February 1985 hearing before the House Subcommittee on Human Rights and International Organizations, one AID official claimed that the FY 86 program included no less than 253 biological diversity projects. Clearly, most of these projects are at best only making indirect contributions to resolving the problem. One constraint on AID's present approach to biological diversity may be a tendency to assume that since biological diversity depends on or is related to so many factors, it is already being addressed by AID's existing programs. Another major contstraint on AID is that it does not have programs in some important tropical countries (e.g., Brazil, Colombia, Venezuela).

USAID has a number of opportunities to more effectivley address preservation of _in situ_ biological diversity. It could greatly increase its cooperation with NGOs. While support to PVOs offered through the Office of Private and Voluntary Organizations (largely through the Food for Peace program) may have beneficial indirect effects in preserving biological diversity in some areas, contacts with NGOs could be expanded. It should give systematic attention to new budgetary and contractual mechanisms to facilitate funding of small projects through NGOs, such as IUCN and WWF, but also indigenous peoples NGOs and other organizations with the capability to administer small projects involving the participation of local peoples. NGOs have had successes in securing the cooperation of local-communities in conservation as well as taking pressure off endangered habitats and designing innovative land management plans directed at meeting local peoples' needs in conjunction with conservation. (see p 30 below) AID should further identify new projects specifically designed to preserve biological diversity, and make more extensive use of the technical knowledge of conservation extant in US agencies such as NPS, FWS, and the US Forest Service to train host country personnel in resource managment techniques. While AID Country Environmental Profiles are useful planning documents, AID should agressively pursue elaboration of National Conservation Strategies, as proposed by IUCN, since National Conservation Strategies are directed toward commitment to specific actions rather than simply resource inventories and the collection of data.

B. The Export-Import Bank

The Eximbank provides loans, loan guarantee and insurance programs to supplement and facilitate private sector financing of U.S. exports. In past years sales of aircraft, nuclear facilities and goods and services for hydroelectric power, mining and oil producing facilities have been among the most important Eximbank financed activities. Total Eximbank program authorizations have been more than $10 billion annually in recent years. There is no question that a number of large development projects in Third World countries that the Eximbank helps finance in the hydroelectric and mining sectors have significant impacts on *in situ* biological diversity. It is important to note, however, that Eximbank participation in such activities is often as a co-financer in large scale projects whose financing and planning are coordinated and led by international development agencies such as the World Bank and USAID. Thus, one significant way of ensuring that Eximbank participation in development projects does not adversely impact biological diversity is to ensure greater and more thorough attention to preservation of *in situ* biological diversity by the multilateral development banks and USAID.

Like USAID and the Overseas Private Investment Corporation (OPIC), the Eximbank was required by Executive Order 12114 concerning "Environmental Effects Abroad of Major Federal Agencies" (*see* discussion in section I.) to adopt procedures for reviewing the environmental impacts of its activities outside the

U.S. The Eximbank issued its procedures in 1979 (12 C.F.R. 408, 409). These procedures are seriously flawed in that they only apply to projects financed under its direct lending program, and not to its risk insurance activities, which account for more than half of its program commitments. This situation is anomolous, given that OPIC is required to review its insurance activities for environmental impacts and may soon have to conform with the environmental directives set out for USAID in Section 118 of the Foreign Assistance Act if a proposed amendment to OPIC's charter is approved by the Congress in 1985.

One of the principal weaknesses of the current Eximbank environmental review procedures is that they fail to address impacts of major projects the Eximbank helps to finance relating to destruction of *in situ* biological diversity. Such impacts include tropical deforestation, destruction of protected natural areas and impacts on lands of indigenous peoples.

C. Overseas Private Investment Corporation

The Overseas Private Investment Corporation (OPIC) is an agency of the U.S. Government which insures U.S. private investments abroad against political risk. OPIC also has a very small direct lending program. In Fiscal Year 1983, OPIC issued $3.9 billion worth of insurance coverage for more than 100 separate projects, in such sectors such as manufacturing (49% of commitments), agribusiness (21%) and minerals and energy (8%).

In its charter, approved by Congress in 1969, OPIC is directed to "complement...the development assistance objectives of the United States...." (22 U.S.C. sec. 2191 (g)). In 1974, Congress recognized the projects financed by OPIC might have significant environmental impacts and directed OPIC to develop environmental regulations. In 1979, OPIC adopted stronger environmental review regulations to comply with Executive Order 12114 (see discussion in Section I. of Executive Order 12114). Congress in 1985 is considering a bill--H.R. 1703--that would require OPIC's criteria for deciding whether to support a project be "consistent with Section 118 [of the Foreign Assistance Act] relating to the environment and natural resources of developing countries." Section 118 gives USAID a strong mandate to consider important aspects of biological diversity in its activities, including conservation of tropical forests and mitigating impacts of projects on flora and fauna.

As in the case of the Eximbank, a number of projects that OPIC helps to support have multilateral development banks or other aid agencies as co-financers, and OPIC relies in such cases on the environmental assessments of these agencies. Promoting rigorous attention to biological diversity concerns within the MDBs and USAID will thus also have an effect on the impact of some OPIC activities on in situ conservation of biological diversity.

OPIC's developmental mandate--its charter is part of the

Foreign Assistance Act and the Administrator of USAID is Chairman of its Board of Directors *ex officio*--calls for a much greater focus on the environmental and natural resources sector as well as environmental procedures and staffing that would more closely correspond to the progress USAID has made in this area. The recent addition of Section 119 concerning biological diversity to USAID's mandate calls for a corresponding changes in OPIC's environmental review procedures to give special scrutiny to prospective impacts on biological diversity.

D. Department of State

The Department of State is involved in a wide range of of conservation activities through its Bureau of Oceans and International Environmental and Scientific Affairs (OES). The Department of State also facilitates much of the international work of the National Park Service and the Fish and Wildlife Service. The Department actively supports and monitors the implementation of CITES and other treaties and agreements relating to conservation internationally, including negotiating with other governments on such agreements.

In addition, the Department is responsible for the US Man in the Biosphere Program Secretariat. UNESCO's Man in the Biosphere Program (MAB), with 105 participating nations, had as of 1983 226 reseves in 62 countries. While MAB reserves in most countries lack legal protection, this program has made crucial innovations in addressing key conservation issues. The goal of MAB has not been to remove human populations from protected areas but rather to incorporate local populations into planning and management of reserves. Zones within the biosphere reserve provide for varying types of land use to accomodate strict protection of natural areas as well as the needs of local peoples for subsistence and income. Local peoples then have a stake in ongoing conservation of resources, and can act as a buffer against incursions by outsiders rather than having an incentive to poach or otherwise violate protected areas as when they are excluded.

US MAB has already allocated funding to a number of international efforts, including a study of relationships between hunting and faunal resources in Zaire and a study on indigenous agricultural and biological diversity in the Sonoran Desert (in Arizona and Mexico). (Department of State 1984) Because the MAB program addresses the key issue of local peoples' relations to the environment, this program has great potential to contribute to the preservation of biological diversity.

MAB's Project No. 8, "Conservation of Natural Areas and the Genetic Material they Contain" clearly addresses biological diversity. Since it is widely recognized that traditional cultivation systems may maintain and use primitve cultivars, and that wild or semi-wild relatives of important crop plants may exist in association with them under traditional conditons, establishing and protecting MAB reserves in the Vavilov centers should be a high priority for the program, and should be pursued by the U.S. State Department.

Various authorities have already suggested that maintaining inidgenous agricultural systems as a pressing need for the preservation of biological diversity. (Oldfield 1984; NAS 1978) Discussions have recently begun on creating a new directorate on biological diversity within the US MAB, which could include participation from the Smithsonian Institution, the National Park Service, and the US Forest Service. This would be a positive step toward greater US involvement in the protection of biological diversity, and should be supported by the State Department. The State Department could also influence other industrialized countries to favor international conservation, and promote joint US-European support for the creation of protected areas.

E. Department of the Interior--Fish and Wildlife Service

The Fish and Wildlife Service of the Department of the Interior is engaged in promoting conservation internationally principally through its Office of International Affairs, but also through its Ofice of Endangered Species, Office of Scientific Authority, Federal Wildlife Permit Office, Office of Migratory Bird Mangement, and Division of Law Enforcement. Its mandate to concern itself with international conservation dates to 1900 with the Lacey Act, then slightly later with the Migratory Bird

Treaties. Its efforts include research education, training and technical assistance, focusing specifically on *in situ* conservation particualarly of endangered species. The FWS Office of Endangered Species, for example, plays a central role in implementation of the 1973 Endangered Species Act, and several offices of the FWS are involved in implementation and review of the CITES. The Convention on Nature Protection and Wildlife Preservation in the Western Hemisphere (Western Hemisphere Convention) is a major concern of Office of International Affairs.

While these activites are clearly important to the preservation of biological diversity, the resources of FWS are largely devoted to the US. The Office of Endangered Species, in its international efforts, treats species in trade as its first priority, then species that occur close to the US. Since much of world species loss involves little-studied or unknown tropical species, much of this process remains outside the purview of FWS. A major constraint on FWS is that the development problems at the root of species extinction in developing countries are outside its scope of action. This limitation could be overcome partially by greater use of FWS technical capacity in AID funded or assisted development projects. Use of a scientist from FWS as USAID's biological diversity advisor is one step toward incorporating the extensive accumulated experience in conservation in FWS into U.S. Foreign assistance, but more AID programs in agriculture and other areas should be designed to include habitat conservation components to preserve biological diversity. FWS could provide technical assistance in this area, given its long experience in wildlife and habitat management. Since this technical expertise is potentially transferable, FWS could provide training on preservation of biological diversity not only to wildlife experts and park personnel, but to development planners, provided that AID can design training programs that include conservation components.

F. The National Park Service

The National Park Service does extensive international work in training and technical assistance and institution building, is the lead US agency in implementing the World Heritage Convention, and works closely with IUCN's Commission on National Parks. It has also published materials on conservation, biological diversity, natural resource management, and development planning. It assists in establishing protected areas in cooperative bilateral agreements with various countries, as well as working to implement the Western Hemisphere Convention. The technical assistance, training and research functions of NPS are clearly of great importance to the preservation of biological diversity, but as is the case for FWS, its mandate does not include development issues--poverty,landlessness, unsound agricultural policies--that must be addressed in conjunction with conservation concerns if notable gains are to be made in preserving biological diversity in the developing world.

The opportunites for NPS are much like those for FWS. It is an agency with a great deal of technical knowledge of conservation that should be more closely involved in development planning. NPS's participation in a regional training center for conservation and resource managment in Costa Rica was important in developing a system of parks and protected areas in that country, and regional training centers could be established in other areas. Operating on a regional, rather than a national level would be a good use of scarce resources. It should be emphasized, however, that developing countries cannot be expected to divert already thin funding from other priorites, such as agriculture and nutrition to set up protected areas, and that U.S. expertise in conservation will have little effect unless it is offered in conjunction with development assistance.

G. US Department of Agriculture--Forest Service

The major involvement of the Forest Service in developing countries has been through the Forestry Support Program, which represents a positive step toward using US government technical knowledge for conservation in conjunction with development programs. The FS also operates two research institutes, one in Hawaii and the other in Puerto Rico, which between them are the largest tropical forestry research program in the US. The

International Office of FS cooperates with the US MAB Program, and may be involved in a proposed new MAB directorate on biological diversity. FS has also loaned foresters to the Peace Corps for use in Peace Corps forestry projects.

Given the importance of tropical forests to biological diversity worldwide, FS should be encouraged to increase its research in this area, and the Forestry Support Program should be expanded and given explicit directions to focus on biological diversity. The Forestry Support Program can call on very great technical expertise, but with the resources presently available to it, does not devote much time to training specifically in the area of biological diversity.

H. Inter-American Foundation

Although it is a small agency with a very small budget in comparison, for example, to AID, the IAF has developed exceptionally promising and innovative approaches to integrating development and conservation. Established under the Foreign Assistance Act of 1969 (PL 91-175), the IAF is an independent government corporation founded explicitly to provide a new approach to development assistance in Latin America and the Caribbean. Its goals include stimulating self-help efforts and encouraging wider particiaption in the development process. The IAF does not design development projects, but rather responds to proposals from grassroots organizations that are already engaged in innovative efforts to increase income, improve health, provide credit, create employment, etc. It actively seeks to fund projects that will become self-sustaining after the IAF funding period and that can be replicated in the region. Because of this focus on ongoing self-help efforts, the IAF has been involved in conservation projects actively promoted by local people, that therefore have organized constituencies supporting them. One example is the Udirbi project (now called Nusagandi), proposed and implemented by the Kuna Indians of Panama. It is potentially a model for the involvement of indigenous peoples in Latin America in environmental planning and protection, including protection of in situ biological diversity.

The Udirbi project responds to the Kuna's need to protect their traditional lands on Panama's Atlantic coast. The Kuna originally attempted an agricultural colony in the Udirbi area, a mountain forest recently opened to outside settlers by a penetration road. Discovering that the area was unsuitable for agriculture, the Kuna proposed a forest and wildlife preserve. The IAF and other outside sources were approached for assistance but initial funds were put up by the Union dos Trabajadores Kuna, the labor cooperative of the Kuna. The project has provided the Kuna with training in forestry and park management, and facilities are being constructed for scientific research and tourism. (Breslin and Chapin 1984; Chapin nd)

Udirbi illustrates that inidigneous peoples can play a central role in the preservation of biological diversity. Where conservation can help indigenous groups protect their lands, increasingly under pressure worldwide,the indigenous peoples are uniquely motivated defenders of protected areas, often with profound knowledge of local plant and animal species.

It is worth noting that IAF, although it funds many fewer projects per year than larger development agencies, has in recent years funded a susbstantial number of projects that inlcude conservation components. The IAF should serve as a model for small, decentralized grassroots assistance. The Inter-Ameircan Development Bank has provided some funding for the IAF's activities, and this suggests innovative steps the larger development agencies could take in this direction. Since one reason the IAF has been able to develop its innovative approaches is that it is a small and flexible organization, large increases in the scale of the organization would not increase results. Rather, USAID and the multilateral banks should be encouraged to allocate funds to conservation and anthropological NGOs with direct experience in and relations to developing countries to administer small projects of the kind IAF has pioneered. Working on the community level in response to perceived needs of people in the community ensures that technical assistance is appropriate and sought after, which in turn increases the likehood that the desired results, such as protection of biological diversity, will be realized.

Even projects not including specific conservation components can have positive effects in preserving biological diversity when they give populations in rainforests and other such areas sustainable ways to use local resources and so take pressure off of endangered habitats. The IAF's Ayoreode-Zapoco Communal Sawmill is one example (Davis 1985). The project in eastern Bolivia was proposed by an indigenous peoples' NGO, and includes training in sustained yield forest management as part of an attempt to generate income for the impoverished Ayoreo community. Such projects also address the causes of species loss and the US government should find mechanisms to devote much greater resources to these initiatives.

I. Peace Corps

The Peace Corps had some 500 volunteers in 47 countries working in the areas of forestry and natural resources as of 1981. About 25% of these are directly involved in conservation or park planning, while the rest work on projects in reforestation, agroforestry, dune stabilization, village fuelwood lots, and other training and development activities that indirectly promote the preservation of biolgical diversity by attempting to improve living conditions for the rural poor, thereby relieving pressures to degrade habitat areas. One new program is a food for work reforestation project in Africa. The Peace Corps collaborates with USAID, the Forest Service, National Park Service, and a variety of NGOs and PVOs to provide training, not only to Peace Corps volunteers, but to host country officials, and local counterparts to volunteers in forestry and natural resource management, including conservation. Since Peace Corps volunteeers spend relatively long periods in local communities in areas with severely threatend habitats, the program offers opportunites for environmental education and community level projects emphasizing sustainable development. The Peace Corps has staff on loan from the Park Service and the Forest Service, but these connections could be expanded. The Peace Corps has had a positive impact in nursery development, and environmental education on the local level. But forestry training is presently a low priority within the agency, which has had requests in this area that it is unable to meet. That there have been such requests from developing countries is a positive sign, and presents opportunities for the Corps to increase its links with FWS and FS, which could provide training in forestry and conservation. The Peace Corps should place a higher priority on village forestry and conservation projects, which it is in a position to carry out at the community level.

V. The Multilateral Development Banks

The most immediate positive effect of Multilateral Development Banks (MDBs) on the preservation of biological diversity is in the creation of protected areas. In this area, as in others, the World Bank has been the leader. The Bank has financed the protection of 59,000 square kilometers in seventeen countries, in the course of forty development projects. It has on occasion funded entire conservation projects, as in a wildlife reserve and tourism project in Kenya, and more often has included conservation components in larger projects, as for example in a protected natural area in conjunction with an irrigation project in Indonesia. In this project the protected area preserves tropical forest and wildlife while providing key watershed management services. Even conservation components that represent a small fraction of a project's cost can play a substantial role in preservation of biological diversity. (In the extreme case, conservation components may have no cost, as when they involve excluding an area from a development project). In this regard the World Bank has taken an innovative step in designing conservation into a variety of development projects in the agriculutre and power sectors in particular. This represents an important opportunity for other multilateral and bilateral development agencies. A major constraint on the World Bank is that it has as yet no policy concerning the preservation of biological diversity *per se*, although a policy statement on "Wildlands Management" is said to be in the final stages of preparation. With its extensive experience, the Bank could once again lead the MDBs by adopting a biological diversity policy.

The Asian Development Bank's creation of Country Environmental and Natural Resources Profiles is a positive step towards improved environmental protection, especially given the great influence of MDB (particularly World Bank) country studies. Adopting such studies is an opportunity for the other MDBs, as is the inclusion of environmental analysis in regional development planning. (Rees 1985)

Since the Multilateral Banks have the largest influence on development policy and financing of any multilateral or bilateral institutions, their influence over environmental aspects of development, including the preservation of biological diversity is similarly greater than that of other institutions. It is now generally accepted that sound environmental management must go hand in hand with development (IUCN 1980; Goodland 1984); consequently, the MDBs are uniquely situated to promote beneficial environmental policies, including promoting preservation of *in situ* biological diversity. (Rich 1985) In 1983, the four MDBs (the World Bank, the Inter-American Development Bank, the African Development Bank, and the Asian Development Bank), lent over $20 billion to fund projects in developing countries, nearly three times the amount committed by USAID, the largest bilateral agency. In 1983 alone, the World Bank alone made loan commitments of over $15.3 billion to fund 301 projects in over 80 countries. (World Bank 1983) Net disbursements from ongoing commitments totalled $4.5 billion for the World Bank and $1.73 billion for the IDB, and net disbursements for the four MDBs accounted for more than 20% of all development assistance in 1983. (Rich 1985)

The impact of MDB assistance on the environment and on in situ biological diversity in the developing countries is even greater than the dollar amounts of their annual loan commitments would indicate. Funds lent by the MDBs are complemented by larger sums from the governments of recipient countries, and many projects recieve co-financing from other development agencies and private banks. For every dollar lent by the World Bank, more than two additional dollars are raised from other sources (World Bank 1983). The IDB attracts three additional dollars for each dollar it lends. The IDB, for example, had lent a cumulative $25 billion for all projects from 1960 to 1983, but this represented a total project cost of over $91 billion. (Ibid.) However, some analysts think that the World Bank's role in the "international marketplace of ideas"--the publication of sector policy papers (eg, in Forestry, or Agriculture), the annual World Bank Development Report, and the Bank's own research on key development issues--is its most important activity. (Ayers 1983)

The policy influence of MDB loans is also increased by increasing portions going for extension, research, training, technology transfer, planning, and other forms of institution building. Many countries orient and modify their development policies and priorities for entire sectors in response to the suggestions and pressures of the MDBs. An important element in this policy influence is the developing country sector work of the MDBs, the general policy documents which the banks produce as background material to help identify priorities in lending.

The World Bank also seeks to promote policy changes in whole sectors, such as agriculture, through structural adjustment and sector loans. Bank officials have commented on the superior leverage of structural adjustment lending, which permits the Bank to promote the alteration of entire national economies. (Stern 1982) Over the past two years, the Bank has committed 10% of its loans for structural adjustment and sector "non-project" loans, the maximum currently allowed for this type of lending under the Bank's Articles of Agreement.

While borrower priorities are clearly a constraint on MDBs,in many developing countries, MDB policy influence, whether direct or indirect, is the most important single influence on the development model adopted. Since agricultural, rural development, and energy polcies have profound effects on the habitats that support the world's remaining reserves of biological diversity, the fate of biological diversity in the developing world is very significantly affected by MDB policies. The effect of this policy influence, given its magnitude, may be either highly beneficial or highly deleterious.

Environmental Policies of the MDBs and the Preservation of in situ Biological Diversity

The performance of the MDBs in the preservation of biological diversity clearly depends on their more general environmental policies, and on the degree to which these policies are effectively implemented. In this regard, the banks, especially the World Bank, have issued or supported high-level policy statements emphasizing the need for sound environmental management in development projects. (Clausen 1981) It is safe to say that it is now universally accepted that development that erodes the natural resource base of developing countires is ultimately self-defeating and as such must be avoided. (World Bank 1984; IDB 1985)

In 1980, the World Bank, the IDB, the Asian Development Bank, and and six other multilateral development agencies signed the "Declaration of Environmental Policies and Procedures Relating to Economic Development". As a result, the MDBs and six other multilateral aid organizations formed, under the auspices of UNEP, a Committee of Internationl Development Institutions on the Environment (CIDIE), which has met five times since 1980 to exchange information on the progress and plans of the MDBs for improving their environmental performance. Under the terms of the agreement the agencies agreed to systematic environmental analysis of activities funded; support for programs and projects designed to solve environmental problems and manage resources sustainably; and, support for improving environmental policy making institutions and their capacity to implement environmental controls in developing countries.

A study, prepared by the International Institute for Environment and Development for the fourth CIDIE meeting, resumed its findings on the MDBs' environmental progress in the following terms:

> The fact that we found so little evidence of the application of existing guidelines suggests that either they have been tried and found useless, or that agencies have not made sufficient resources and incentives available to sustain their use. We suggest that some agencies never put some guideliens into operation because their function is to improve public relations... In many cases, staff do not use guidelines becuase agencies do not require their use, nor provide appropriate training and resources nor establish any institutional penalties for failing to use them. (Horberry 1983)

Environmental concerns at the four major MDBs are institutionally addressed as described below:

World Bank

The World Bank's Office of Environmental and Scientific Affairs (originally Office of Environmental Affairs) was established in 1970. The World Bank leads the multilaterals in environmental planning. Of six fulltime professionals in the Office, three are involved in reviewing some 315 projects a year as well as monitoring hundreds of ongoing projects a year. Up to 1984, the Bank's sole mandatory environmental procedure called for review of projects already appraised, just before the start of loan negotiations. OESA attempts to intervene earlier in the project cycle, in the identification and preparation phases, but lack of staff and established procedures make this an *ad hoc* process. OESA also attempts to indirectly influence project staff and produces extensive literature. The Bank's country and policy papers, which are extremely influential planning documents, often contain no environmental assessment or appraisal of natural resources in light of possibilities for or impediments to sustainable development. One analyst noted, "Despite strong policy statements by both the previous and the present World Bank presidents about environmental protection and sustainable development, at an operational level much of the preparation and implementation of bank loans is free of routine environmental analysis." (Horberry 1983)

Inter-American Development Bank

The IDB has no environmental office, no environmental staff positions, and no mandatory procedures to be followed for environmental review of projects. The IDB does have environmental checklists for various sectors, and issues guidelines to borrowers, but no procedures for the integration of these into the project cycle exist. The IDB also has an Environmental Management Committee, composed of high-level project staff and managers, but the operational function of this council is not clear. The IDB claims to integrate environmental concerns fully into the process of project appraisal and review and includes environmental management components in some loans. (IDB 1985) Unlike the World Bank, the IDB has no policies concerning the setting aside of protected areas in its projects.

Asian Development Bank

The Asian Development Bank has an Environmental Unit with a staff of two persons out of a total operational and projects staff of about 320. It has no requirement for environmental assessment and clearance of projects, although projects have been regularly reviewed by the environmental staff since 1981. The unit attempts to identify crucial points in the project cycle and integrate environmental criteria on an ad hoc basis, and would like to influence projects at an earlier stage since environmental planning is more effective "upstream" in the decision making process. The Environmental Unit has prepared checklists for various sectors, which are distributed to Bank staff.

One promising initiative is the preparation of country environmental profiles by the Environmental Unit. Unfortunately, the efforts of this unit are constrained, as in the World Bank, by understaffing and lack of influence on the project cycle. As with the two other regional MDBs, the Asian Bank has no policies concerning the setting aside of protected areas of any kind, not to speak of preservation of in situ biological diversity.

African Development Bank

The African Development Bank has hired an environmental staffer for the first time in 1985, which suggests an awareness of the need to consider environmental planning. There are no formal procedures for environmental review of projects, but the chance of effective intervention may evolve given adequate support and an ability to proceed on a piece-meal basis. Policy and procedures may be established such that modifying or averting environmentally unsound projects could be attained.

The most positive area of MDB environmental performance has been in loans aimed at preserving a functioning resource base for rural people in the developing countries. The World Bank, for example, has in recent years changed its forestry lending priorities to focus on environmental forestry - rehabilitation of watersheds, village fuel woodlots, reforestation of marginal lands, etc. The ADB and IDB have policy to support natural resource management projects when requested by borrowers. In Asia especially, developing country governments are giving increasing attention to environmental and natural resource planning, and the ADB has funded a number of integrated regional planning projects, which include environmental/resource planning.

Clearly, environmental considerations could be more thoughroughly incorporated into MDB development planning, with very positive effects on the preservation of biological diversity in the developing world. In 1983 and 1984, a US environmental policy for the MDBs evolved which suggests concrete measures that could be taken in this direction. Since US influence in the MDBs has traditionally been strong, a concerted effort from the US executive directors could improve MDB environmental performance in general, and make significant contributions to the preservation of biological diversity in the developing world. Following a series of five hearings on environmental impacts of MDB-financed development in 1983 and 1984, the House Subcommittee on International Development Institutions and Finance issued a series of recommendations to the US Treasury Department, in effect proposing a US environmental policy for the MDBs. These recommendations were largely supported by the Treasury Department, the lead Federal agency for US participation in the MDBs. The recommendations include increased environmental staffing and mandatory procedures for project review, as well as calling on the U.S. Executive Directors to press for modification of or to oppose projects that would erode the natural resource base or destroy sensitive habitats. The recommendations address a number of the concerns highlighted by the Interagency Task Force on Biological Diversity--institution building and training for conservation and better management of protected areas in developing countries; involvement of indigenous peoples in development planning; and withdrawl of support for projects that cause extensive damage to habitats in species-rich areas. (see annex 1) The U.S. could take a major step in promoting the conservation of in situ biological diversity by vigorously implementing these recommendations. The Treasury Department and the U.S. Executive Directors should take this opportunity.

Recommendations number 3, 4 and 5 ,which deal with environmental staffing and review procedures, are of great importance to the preservation of biological diversity, since under present conditons environmental staff (where there is environmental staff) is so overburdened that the identification of problems, such as habitat destruction, is possible only in a fraction of the projects approved. Creation of environmental staff positions in all the MDBs, including positions in the regional offices of the World Bank, would allow better review of projects at earlier stages in the project cycle and permit identification of problems and inclusion of appropriate conservation components.

Recommendation number 14, which deals with the US voice and vote the MDBs, is of particular importance in defining steps that the US government can take to protect biological diversity worldwide. This recommendation details criteria to be applied by the U.S. Executive Directors to determine whether environmental considerations should compel the U.S. Directors to seek changes in proposed projects, or in the worst case, to oppose environmentally destructive projects. Prominent among these criteria is concern with protection of biological diversity. The recommendation states in part, " the U.S. Executive Directors (should) oppose any project which, in its final form, (a) results in using of natural resource harvests at an unsustainable level within a population or ecological unit; (b) threatens to cause species extinction or to endanger species survival; (d) is expected to significantly convert or degrade those minimal and already overtaxed designated natural areas including national parks, wildlife reserves, world heritage sites and biosphere reserves which serve as the last vestiges of sanctuary for many forms of life; (e) threatens to significantly impair the land and resource base upon which inidgenous peoples depend,". (House Subcommitte on International Development Institutions and Finance 1984). Implementing this recommendation is an important opportunity for the preservation of in situ biological diversity, since it calls for a clear US stand on those projects still financed by the MDBs--despite their policy statements in favor of sustainable development--that contribute to massive species extinction through habitat destruction. (Ibid.)

Congressional oversight hearings in 1983 and 1984 brought to light substantial evidence of serious ecological problems and damage resulting from MDB projects currently in progress. (House

Subcommittee on International Development Institutions and Finance 1983, 1984; House Subcommittee on Natural Resources, Agriculture Research, and Environment 1984) MDB projects that are capital rather than labor intensive have contributed to the displacement of large numbers of rural poor and landless peasants from lands suitable for agriculture to marginal lands,such as tropical forests, which are often important resevoirs of biological diversity but of limited agriucltural potential. In some cases the MDBs continue to finance resettlement projects that result in deforestation of tropical moist forests. (Rich 1985; Lutzenberger 1984) There is also evidence that promoting export agriculture based on the classic export commodities such as coffee, sugar, tobacco,etc, under prevailing conditions of global oversupply has reached a point of diminishing returns and that reducing production of export commodities would entail greater immediate economic benefits for the exporting countries. (International Agricultural Development 1985) Such a reduction would in additon reduce pressure on biologically diverse marginal lands, such as tropical forests, and could reduce dependence on genetically uniform, vulnerable commodity species. In any case, tropical forest resettlement schemes have a poor record and immense environmental costs. (Guppy 1984; Rich 1985; Aufderheide and Rich 1985; Schwartzman 1985) Such projects should not be supported by the MDBs.

Another category of project with low economic returns and high environmental costs, including destruction of species rich habitats, is cattle ranching in the tropics. MDBs have financed cattle projects, especially in Latin America, on such a large scale over the past twenty years that no other single commidity has ever recieved such extraordinary outside support as livestock in Latin America. (Feder 1979) In many countries MDB financed agricultural credit loans have been the decisive factor in furthering livestock development. In Costa Rica, for example, nearly half of all agricultural credit through the late 1970s went for livestock. (*Ibid.*) A substantial body of evidence indicts cattle ranching in tropical forest areas as one of the least suitable and most economically wasteful of all development alternatives. Pastures occupy huge areas with low concentrations of cattle per hectare, and pastures are extremely prone to convert to wasteland after a few years, because of declining soil nutrients, invasion of toxic weeds, soil compaction, and overgrazing. Few jobs are generated by cattle projects compared with other investment alternatives. (Fearnside 1983; Goodland 1980; Hecht 1983; Nations 1983) Virtually any development alternative to cattle ranching in tropical forest areas promoted by the U.S. Executive Directors to the MDBs would constitute a positive step toward preservation of *in situ* biological diversity.

Large scale hydroelectric power projects and irrigation systems also entail severe environmental consequences, including destruction of biological diversity. (Blackwelder 1984; Bramble 1983) Major environmental problems resulting from large scale water projects include not only the innundation of areas, often tropical forests, of great biological and scientific significance, but salinization and waterlogging of irrigated lands (leading eventually to increased pressure on marginal lands), forced displacement of large numbers of people, often including indigenous groups with specialist knowledge of remote, highly diverse ecosystems, and the siltation and sedimentation of resevoirs and channels through deforestation of adjacent watersheds. Such projects should be replaced by alternatives wherever possible and much more carefully scrutinized for environmental impacts, as recommended by the Congress.

The halting of MDB projects that directly contribute to habitat destruction constitutes a major opportunity for the preservation of biological diversity in the developing world, and implementing the Congressional recommendations is a concrete step the US government can take in this direction. The recommendations also include positive steps the MDBs can take to improve environmental protection in general and preserve in situ biological diversity in particular.

The steps that the MDBs can take that would result in greater preservation of biological diversity include the use of appropriate ("light capital") technologies, research on and incorporation into project design of alternative land management techniques, and involving local indigenous and conservation NGOs in project planning and implementation. These are indicated in recommendations 8, 9, and 11. The involvement of indigenous groups in the development process in general and particularly in environmental protection is an especially good opportunity for the MDBs. In many parts of the developing world, indigenous peoples have the most sophisticated and complete knowledge of the characteristics of the ecosystems they inhabit, especially unstudied tropical forest areas. (Posey 1984; Prance 1982) A model example of how indigenous groups can be involved in environmental protection, while activley participating the development process is the Udirbi project in Panama, partially supported by the Inter-American Foundation, USAID, WWF, and the Smithsonian Tropical Research Institute. (see below, VI F,G) Involving indigenous groups in project design and environmental protection has the additional advantage that many of the most promising alternative resource management techniques derive from indigenous land use systems.

There are a number of underexploited resources and techniques whose sustainable utilization would promote rather than undermine conservation of in situ biological diversity. Among the alternative resources and techniques that deserve serious attention from the MDBs are the riparian fauna and fish of the Latin American tropical forests (Goodland and Irwin 1975), indigenous forms of wildlife (Castillo 1981), home and orchard gardens, (Goodland 1981),ridged fields and jungle terraces (Nations and Komer 1983). Several promising alternative resource management techniques have been described from tropical Central America - Lacandon agroforestry and precolumbian chinampas. Chinampas are a form of self-sustaining ,labor intensive agriculture in which small plots of land are built up and separated by irrigated channels. The soil in these plots is continually built up with organic material from the channels, which abound in nitrogen fixing plants and small aquatic animals. Research and pilot projects conducted in Mexico have investigated how this system might be modified and reintroduced on a large scale in humid tropical areas. These projects have been successful, and a system of chinampas and agro-forestry has been proposed as a conservation oriented alternative to current patterns of land use in many tropical forest areas. (Maier 1979; Gomez 1978; Nations and Komer 1983)

The Lacandon Indians of southern Mexico have preserved many of the ecological skills of their Maya ancestors and have developed a system of agro-forestry that could provide the model for sustained development throughout the region. Typically, Lacandon farmers plant only 0.75 ha. of land, but they pack these small plots so densely with cultigens that little weeding is required once the plot is initially cleared and begins to grow. From this "cultivated jungle" they harvest up to 40 different kinds of plants, including a much wider variety of food crops and medicinal herbs than is grown by neighboring colonists. Lacandon corn yields five tons per hectare, whereas jungle colonists seldom exceed two tons per hectare on their plots, and must abandon them after two or three seasons. Lacandon plots attract wildlife, providing game, and yield tree crops for much of the fallow period. (Nations and Komer 1983)

The MDBs are conspicuous through their lack of attention to alternative techinques of resource management, and should do much more research on such techniques and implement pilot projects that use them. Aside from the creation of protected areas, the aggressive pursuit of alternative land use models that offer sustainable yields of food crops for the tropics is perhaps the greatest opportunity available to the MDBs for preserving in situ biological diversity. The World Bank in particular has made progress in establishing protected areas in conjuntion with projects, but should have an explicit policy on the preservation of biological diversity to help guide its conservation efforts.

VI. Private Voluntary Organizations and Nongovernmental Organizations

The OECD directory of NGOs lists 4,000 NGOs for the developed world alone, and these include a wide variety of organizations. Some, like the World Wildlife Fund, are conservation organizations, while many of the oldest and largest PVOs, such as

CARE, started as disaster relief organizations and continue to devote major portions of their resources to this area. Most importantly for the maintenance of in situ biological diversity, conservation NGOs and PVOs have come to recognize the necessity of integrating conservation with development to address the causes of habitat destruction, as propounded in the World Conservation Strategy, while organizations such as CARE and Church World Services have increasingly emphasized community development, including land reclamation, afforestation, reforestation, soil conservation, and a series of measures to increase food production and income. (Bolling and Smith 1982; Boynes 1978) To the extent that these organizations can improve living standards and foster community self-sufficiency, they can help reduce pressure on threatened habitats and reduce the destruction of biological diversity.

PVOs and NGOs typically share an orientation toward local participation, self-sufficiency, and the creation of community level projects that can become self-sustaining (Gorman 1984; Masoni 1985). This orientation, their size, and their focus on community level work distinguishes them from multialteral and bilateral aid agencies, and NGOs and PVOs have a good reputation for mobilizing communities. (Masoni 1985; Tendler 1982) However, recent work points out that too little is known about what makes successful community development replicable, or self-sustaining. (Gorman 1984a; Tendler 1982) NGOs and PVOs often fund pilot projects, and have a reputation for innovative approaches, but may lack resources to sustain promising projects in the longer term, particularly where these have high recurrent costs. (Gorman 1984) One development that represents an opportunity both for larger assistance agencies and NGOs and PVOs is increased communication and cooperation among these organizations. (WRI 1985) The World Bank's NGOs Committee and the Interamerican Development Bank's small projects program are two such intitiatives.

One step toward improved communications among NGOs and multilateral and bilateral aid agencies in areas of immediate importance to the maintenence of biological diversity was the conference sponsored by the Inter-American Foundation in September of 1985 on indigenous peoples, rural development, and natural resource managment. Representatives of the World Bank, the Canadian International Development Agency, Catholic Relief Services, World Wildlife Fund, and Cultural Survival, among others, met to compare the respective strengths and weaknesses of their organizations in the areas of indigenous peoples' protection and participation and environmentally sound resource use in rural development. These organizations have much to offer each other. NGO and PVO staff typically have long direct experience in local communities, as well as networks extending from third world communities to NGOs in the developed countries. The larger agencies have resources and experience with longer term projects that could be of great value to NGOs and PVOs. Increased exchange among the two types of organizations, and increased attention to evaluating novel approaches developed by NGOs and PVOs at the grassroots level (Ellis 1984) could lead to more effective rural development that would assist in reducing habitat destruction and unsustainable use of natural resources.

A. CARE

CARE had an overall budget of $250 million in 1982 and operated in 36 countries. (Bolling 1982) The majority of CARE's programs were for hunger relief, but the organization has also funded projects involving soil conservation, reforestation, and watershed management, which address the causes of habitat destruction at the community level and so can help to ease the problems that lead to reduction of biological diversity. In 1978, CARE's expenditures included some $185 million in development assistance (Boynes 1978). Insofar as such assistance succeeds in improving living standards in poor communities,it contributes indirectly to the preservation of biological diversity. Under the" CARE for the Earth" campaign, CARE has implemented a variety of resource conservation and agroforestry programs, using village fuel woodlots, tree nurseries, and other agroforestry techniques to reclaim and protect natural resources at the community level.

For example, in Niger, CARE is involved in several projects that include planting windbreaks to halt wind erosion, dune stabilization through planting millet stalks and trees, riverbank protection, and village tree nurseries. (CARE 1985) There is also an evaluation study of the windbreak project underway to assess results and offer recommendations for improvement if necessary. CARE has also been engaged in soil conservation and reforestation in Guatemala, including demonstration plots, fish ponds, terracing, and tree planting. CARE now has some 23 projects in 17 countries in the areas of reforestation, aforestation and watershed management. CARE is partially supported by USAID and has used Peace Corps volunteers in some projects.

These kinds of community level projects have potential for taking pressure off of endangered habitats as well as fostering environmental education. While CARE, like other PVOs does not undertake national level development projects, this is not necessarily an impediment to the effectiveness of the local level resource conservation it aims at. Resource managment projects, as well as other community development, require closer evaluation if they are to be replicable (Tendler 1982; Ellis 1984).

B. Lutheran World Relief

Lutheran World Relief spent some $5 million in 1978 on development assistance. Its focus in this area is on longer range integrated community development, and it has implemented agroforesry, aforestation and reforestation projects, as well as demonstration projects using improved seeds, new crops, expanded gardens, and fisheries. (Boynes 1978) The organization has emphasized environmental education of local people affected by its projects as a means of making the projects self-sustaining. One reforestation project in Somalia succeeded through paying refugees for reforestation work.

This organization has the same kind of indirect, but potentially valuable, effect on the preservation of biological diversity as does CARE, in that it can help to make poor communities less liable to engage in habitat destruction through reclaiming degraded resources and promoting sound management of resources.

C. Church World Services

Church World Services describes its mandate in the development area as attacking the causes of poverty through basic human development, and it spent nearly $5 million out of $18 million in total expenditures in 1978 on development. (Boynes 1978) It has funded projects in land tenure, reclamation of land, reforestation, irrigation, desalinzation, crop improvment, and soil conservation.

D. Catholic Relief Services

Out of total budget of $291.5 million in 1978, Catholic Relief

Services spent $215 million on self-help oriented development projects. (Bolling and Smith 1982) As is the case for many of the larger PVOs, which recieve US agricultural surplus through the USAID Food for Peace program, food for work is a major component of its programs. Successful projects reported for the organization exemplify the reputation of PVOs for innovative, grassroots approaches to development. A program of agricultural cooperatives in Sengal, the Wassadom Agricultural Development project,is said to have achieved notable local self-sufficiency, while another project in Bolivia succeeded in building a market for the indigenous pre-columbian crop quinoa, improving the income of peasant communities. (Bolling and Smith 1982)

E. Pan American Development Foundation

The PADF is a private organization that is financed through gants from major corporations, foundations, individuals and such public international organizations a USAID and the Organization of American States. Its objectives are to strengthen the private sector's role in development in Latin America through providing opportunity to the "enterprising poor". While most of PADF's activities are in such areas as job skills training and health services, it has recently undertaken a reforestation project in Haiti, and has another such project planned for Antigua, as well as a forestry demonstration project in the Dominican Republic.

The Haiti forestry project has apparently surpassed its original goals, with some 20,000 peasants planting 6 million more seedlings than the originally projected 4 million, and will be extended. (PADF 1984) The project aims to halt soil erosion and shortages of fuelwood through encouraging peasants to plant trees on their own land, such that the trees are cash crops.

Since much destruction of biological diversity results from severely impoverished peasants leaving degraded environments to attempt to support themsleves in formerly wild areas, all of the village forestry/agroforestry projects described represent an important tool for the defense of biological diversity insofar as they help to reclaim the resource base and increase income.

F. World Wildlife Fund

The World Wildlife Fund (WWF) is is the largest nongovernmental conservation organization in the world, with 26 national affiliates. In 1984 WWF US disbursed nearly $3 million in grants to conservation projects, in addition to $1.2 million for public information and education. (WWF US 1984)

Both national affiliates and the international organization manage conservation projects, focusing on protecting endangered species, establishing protected areas, educational programs, institution building, and protection of ecosystems. WWF International is a member of and collaborates closely with the International Union for the Conservation of Nature and Natural Resources(IUCN), and the United Nations Environmental Program

(UNEP). These organizations jointly elaborated, published and promote the influential World Conservation Strategy, under the leadership of IUCN. WWF also collaborates to some extent with bilateral and multilateral development agencies, and the expansion of this kind of cooperation is a major opportunity for the preservation of in situ biological diversity.

For example, in 1984 WWF US recieved a $1 million dollar matching grant from USAID's office of Private and Voluntary Organizations to develop field projects in Latin America and Africa under the program in Wildlands and Human Needs. The program follows WWF work in a number of projects that integrate sustainable use of wildland areas with preservation of ecological values, including the Kuna Wildlands Project in Panama, the Darien Biosphere Reserve in Panama, the La Amistad Biosphere Reserve in Costa Rica and Panama, the Rio Platano Biosphere Reserve in Honduras, and the La Planada Nature Reserve in Colombia. (Houseal et al 1985) These projects all involve protection of natural areas while providing for use and management of resources by indigenous populations. Such innovative initiatives that combine local development with conservation concerns represent promising opportunities for the maintainence of in situ biological diversity. Some of the advantages of this approach are discussed in the follwoing section in relation to Cultural Survival's Native Lands Demarcation Project.

G. Cultural Survival

Cultural Survival is a US based NGO that researches and disseminates information on the situation of native peoples internationally. It is a small organization and has been largely concerend with research, publications, and the distribution of information, but has engaged in some innovative development projects involving native peoples that offer new approaches to the protection of biological diversity in the developing world. One such project is the Native Land Demarcation Project, in the Ecuadorian Amazon, developed in collaboration with the National Institute of Colonization of the Ecuadorian Amazon Region. The project carried out detailed land use surveys of the traditional land use patterns of several Amazonian Indian groups and succeeded in getting land title for the indigenous groups in several areas under pressure from colonists. This provides several benefits for the preservation of *in situ* biological diversity.

First, by providing the indigenous inhabitants of a rainforest area with the legal means to defend their land from outside incursions, the project achieved an important prerequisite to reducing the scope of deforestation. The Indians have an overwhelming interest in defending the forest from invasion since they depend on it for survival. Having legally demarcated reserves also gives the indigenous peoples a better chance to preserve their traditional knowledge of the region, which can be invaluable for scientific studies. Researchers associated with the project are working on various alternative resource management systems, including mixed cropping, reforestation, multiple cropping, community forestry, and small livestock raising on family plots. These alternative land use systems offer not only models for sustainable use of forest lands for colonists, but also sustainable means of producing income for Indians on reserves to allow for their changing needs and future population growth. (Uquillas 1985)

Cultural Survival, and other indigenist NGOs can use their extensive networks to identify indigenous groups and indigenous peoples' NGOs in developing countries that could participate in projects similar to the Native Land Demarcation Project, or the Udirbi Project. The possibility of closer collaboration between groups such as Cultural Survival and larger conservation NGOs presents a major opportunity for the preservation of biological diversity. This would increase the possibilities for finding and refining new resource management alternatives. Projects that share the characteristics of the Native Lands Demarcation project and the WWF biosphere reserve projects mentioned above can help put diverse areas into the hands of people who have unparalleled expert knowledge of that diversity and a direct interest in defending it.

VII. Research Institutions

There are several categories of research institutions that make crucial contributions to knowledge of biological diversity. These include the National Science Foundation, government tropical research institutes, such as the Institute for Tropical Forestry or the Smithsonian Tropical Research Institute, botanical gardens in the U.S., such as the Missouri Botanical Garden or the New York Botanical Garden, and several consortia of private universities, such as the South-East Consortium for International Development and Universities for International Forestry. In addition, the MDBs have an important impact on research funding and priorities in developing world institutions concerned with tropical forestry, agriculture, and related topics. The OTA Background Paper #2, "Sustaining Tropical Forest Resources: US and International Institutions" contains a good discussion of the various research institutions active in this area and their roles. (OTA 1983)

Given the enormity of the problem of species extinction and the rapidity with which it is occurring, there is a need for expansion of research particularly in the areas of tropcial biology and ethnobotany. The extent of what is not known about tropical ecosystems is enormous. While figures of 2 or 3 million species globally, of which 500,000 are scientifically named, are frequently encountered, some entomologists think that 8-12 million species is closer to the correct figure, (Department of State 1982), and recent research on the previously inaccessible canopy level of tropical forests suggests that the total may be some 30 million species. (Erwin 1985) The present global expenditure for research in tropical biology is one third the price of a B-1 bomber. Clearly, if the US is to play a leading role in preserving biological diversity the amount spent on research will have to increase. In the basic area of inventorying the species that exist (the indispensible first step for any reasoned preservation of biological diversity _in situ_ or _ex situ_, there are about 1,500 systemic biologists worldwide capable of classifying unclassified tropical species. More expertise will have to be developed in all areas of tropcial biology. Various proposals have been made by qualified experts on what areas are most in need of strengthening. (NAS 1980; Norse 1985) We will confine ourselves to research needs that have been less discussed.

A major difficulty in effectively integrating environmental concerns into development planning is that environmental benefits of undisturbed natural areas are often not immediately amenable to economic calcualtion. Some may be incalculable, for example, the moral value of not causing an irreversible species extinction. Most environmental benefits are, however, probably calculable, and it would aid efforts to preserve biological diversity if more research were done in this area. Various ecologists have pointed out that as long as tropical forest, for example, is regarded as a free good with no production cost, predatory use of forest resources will continue to increase rates of deforestation. (Guppy 1984) Several kinds of research could contribute to better valuation of environmental benefits in development planning.

One such kind of reseach would be independent evaluation of multilateral and bilateral development projects in environmentally fragile areas--tropical forests, coastal areas--carried out by interdisciplinary teams including ecologists, agronomists, and anthropologists or sociologists. Since monitoring and evaluation are recent additions to bank project cycles and are still not always included, independent evaluation of projects that are underway or completed could yield crucial data on what the benefits to local and national economies of MDB and bilateral projects are , and what costs, including environmental ones, were entailed. Such research would also contribute greatly to an overall improvement in development planning, but given the time constraints imposed by MDB project cycles, more environmental and sociological expertise on MDB staffs is still necessary.

This kind of evaluation of environmental costs of development projects could contribute to research already ongoing on how to quantify environmental benefits, e.g, the value of the standing forest as opposed to the value of the commercial timber in it.

Another neglected research area is ethnobotany and the study of indigenous peoples resource management. (Prance 1982; NAS 1970) Ethnobotanic research is useful as a way of selecting from the immense number of little known or unknown plant and animal species those which have potential medical or commercial value. (Oldfield 1984) The virtually unknown area of indigenous peoples resource management promises discoveries not only of useful plant and animal species, but also in techniques of sustained yield long-term management of highly diverse areas, such as tropical forests. (Posey 1985) Recent research has shown a previously unimagined sophistication in resource mangement on the part of indigenous groups still practicing traditional productive activities, many of which are coming under severe pressure to abandon traditional ways of life. (Ibid.) Priority should be given to research on diversified use of tropical forest resources that includes sustainable production for sale on levels that meet community needs for market commodities, eg, native rubber in the Western Amazon (Valle de Aquino 1977), or the mixed cropping and raising of timber species of the Bora (Treacy 1982; Clay 1985)

Another topic that merits research is the environmental impact of International Monetary Fund economic policy. The IMF has very great influence over agricultural and social policy in the developing countries, and its emphasis on production for export may in some cases run counter to, or even override, World Bank environmental policies, for example. The ultimate impacts of IMF economic stabilization programs on the prospects--or lack thereof--for conserving biological diversity in the developing world may be enormous since no single international institution has more polilcy leverage. However this topic remains virtually unexamined. Research in all the areas mentioned offers major opportunites to US research institutions and for funding by the NSF.

VIII. The Private Sector

Some of the activities discussed above in fact involve private sector initiatives. The IAF's empahsis on projects proposed by local level groups that provide their own matching funds and that can become self-sustaining bypasses government involvement and strengthens local community organizations, cooperatives, and other private sector entities. (Wasserstrom 1985) There may also be possibilities for designing tax incentives to encourage conservation initiatives on the part of major corporations. In particular, developing country governments should be encouraged to plan investment incentives with environmental goals, including the preservation of biological diversity, in mind. Subsidies for investment on marginal lands, as in the case of incentives for cattle ranching in Amazonia, speed the destruction of biological diversity and should be halted.(Pearson 1985)

Dr. Thomas Lovejoy of WWF has proposed the idea of "conservation debt credits" for developing countries whereby banks and government agencies would offer limited forgiveness of debt in exchange for expenditures on conservation measures, and this idea deserves more discussion, since foreign indebtedness is a major constraint on all types of government expenditures in tropical debtor nations. Pressure to meet debt payments may itself encourage environmentally unsound resource use leading to destruction of habitat. (Pinto 1982)

On the positive side, it is likely that the idea of conservation debt credits would meet with approval from debtor nation governments. But taking for example the case of Brazil, about 2/3 of the foreign debt is held by private banks, which would have to be either convinced to write off part of their outstanding loans as bad debt, or be reimbursed by governments or multilateral agencies if substantial amounts of money were to be dedicated to increased environmental protection. In the case of multilaterally held debt, some arrangement resembling IDA credits to compensate environmental expenditures seems at least theoretically possible. This would require consensus among the major donor nation governments, and discussion of the idea should be opened. It seems likely that multilateral institutions would have to take the lead if this idea is to be implemented. The central institution in international debt negotations, the IMF, however, construes its role as purely economic, and would probably resist adopting a position on international environmental questions.

Even if it were to prove impossible to devote significant resources to environmental protection through this mechanism, the idea is useful as a tool in environmental education in the developed world. The notion of conservation debt credits leads directly to the observation that deforestation, habitat destruction and species extinction are processes that extend beyond the countries where they are most visible. Citizens in the developed world must understand that substantive steps to check the process will have effects in their own countries and in their own communities (eg, in their banks). The idea of conservation debt credits can be used by environmental organizations with public education and information programs to broach the necessity of concerted international action on species extinction and to suggest that people distant from the physical process of eg, deforestation, can play a role. Such efforts would help to build support for increased bilateral and multilateral action.

Recent reports note that appropriately designed private sector investment in, for example, industrial forestry can help alleviate pressure on endangered habitat (World Resources Institute 1985; World Bank 1978), and that multinational corporations are coming to recognize that environmental concerns in developing nations need not be inimical to their interests. (Pearson 1985) There are however, limits to the extent that private business can be expected to take a leading role in conservation of biological diversity. Corporations typically plan for immediate benefits and will not forgo short term profit in favor of long term gain that they have no control over. Since destruction of biological diversity, through deforestation, pollution, or predatory trade in endangered species benefits some traders, loggers, cattle ranchers, speculators etc. very markedly in the short term, they are not likely to give up these benefits unless they are constrained to do so. Problems in inducing logging firms to reforest are one example. (Caufield 1985) Market forces will not resolve international problems like deforestation, destruction of biological diversity, carbon dioxide build-up, acid rain, or ocean management.

Reorganization, or better regulation of the market in some instances could be useful. Dr. Norman Myers pointed out at the U.S. Strategy Conference on Biological Diversity that since germplasm is traded freely worldwide, there is little incentive for Third World nations to conserve gentic resources. (Department of State 1982) While commercial sales of vinicristine in the developed world are some $100 million annually, no benefits accrue to the tropical nations of origin of the plant that is the source of the powerful anti-cancer agent. In this light, international licensing of germplasm, with rights to commercial products included, would provide a stimulus to the preservation of genetic diversity. Such an initiative would be likely to be opposed by pharmaceutical manufacturers, however.

Bibiliography

Aufderheide, P.; and Rich, B.; "Debacle in the Amazon, " Defenders April/May, 1985.

Ayers, R., The World Bank and World Poverty: Banking on the Poor, Cambridge: MIT Press, 1983.

Blackwelder, Brent,; and Carlson, Fact Sheets on International Water Projects, Washington D.C.: Environmental Policy Institute, 1984.

Blake, R.O., et al, Aiding the Environment: A Study of the Environmental Policies, Procedures, and Performance of the US Agency for International Development, Washington D.C.: Natural Resources Defense Council, 1980.

Bolling, L., and Smith C., Private Foreign Aid: US Philanthropy for Relief and Development, Boulder, CO: Westview Press, 1982.

Boynes, Wynta, ed., US Non-Profit Organizations in Development Assistance Abroad, TAICH Directory, 1978.

Bramble, Barbara J., statement on behalf of National Wildlife Federation, in Hearings before the Subcommittee on International Development Institutions and Finance of the Committee on Banking, Finance and Urban Affairs, House of Representatives, 98th Congress, June 28and 29, 1983.

Breslin ,P.; and Chapin, M.; "Conservation Kuna-Style," Grassroots Development, 8:2, 1984.

CARE, internal evaluation reports, Reforestation and Soil Conservation Program, Guatemala; Bousa Reforestation Program, Niger, ms. 1985.

Caufield, C., In the Rainforest: Report from a Strange, Beautiful, Imperiled World, New York: Alfred Knopf, 1985.

Chapin, M., Project to Assist Union de los Trabajadores Kuna Inter-American Foundation, ms. nd.

Clausen, A.W., "Sustainable Development: The Global Imperative," Washington D.C.: The World Bank (Fairfield Osborne Memorial Lecture), 1981.

Clay, J., "Indigenous Models of Tropical Agriculture and Forest Development in Latin America," paper prepared for US Man in the Biosphere Program, July 1985.

Committee on Foreign Affairs, Committee on Foreign Relations, Legislation on Foreign Relations Through 1983 Joint Committee

Print, 3 Vols., US House of Representatives, US Senate, March 1984.

Davis,Shelton, "The Ayoreode-Zapoco Communal Sawmill: A Social Forestry Project in Eastern Bolivia," Washington D.C.: The Inter-American Foundation, ms. 1985.

Department of State, *Proceedings of the U.S. Strategy Conference on Biological Diversity, Nov. 16-18, 1981*, Washington D.C.: Department of State, 1982.

Department of State, *Conserving International Wildlife Resources: The United States Response*, report to Congress by the Secretary of State and the Secretary of the Interior, December 1984.

Eckholm, E., *Disappearing Species: The Social Challenge*, Washington D.C.: Worldwatch Institute,1978.

Ehrlich,P.R.; and Ehrlich, A.H.; *Extinction: The Causes and Consequences of the Disappearance of Species*, New York: Random House, 1981.

Ellis, G., "Making PVOs Count More: A Proposal," *Private Voluntary Organizations as Agents of Development*, Robert F. Gorman ed., Boulder CO: Westview Press, 1984.

Fearnside, P., "Deforestation in the Brazilian Amazon: How Fast is it Occurring?", *Interciencia* 82-88, 1982.

Feder, E. "Agricultural Resources in Underdeveloped Countries: Competition Between Man and Animal", *Economic and Political Weekly*, 1345-1366, 1979.

Gomez Pompa, A.; "An Old Answer to the Future", *Mazingira*, No. 5, 1978.

Goodland, R.J.A.; "Brazil's Environmental Progress in Amazonian Development," *Change in the Amazon Basin*, Hemming, J. (ed.)Manchester: Manchester U Press, 1984.

Goodland R.J.A.; "Environmental Optimization in Hydrodevelopment of Tropical Forest Regions,"*Man-Made Lakes and Human Health*, Panday, R.S. (ed.), Paramaribo: University of Suriname, 1979.

Goodland, R.J.A.; "Environmental Ranking of Amazonian Development Projects in Brazil," Washington D.C.: The World Bank, 1980.

Goodland, R.J.A.; and Irwin, *Amazon Jungle: Green Hell to Red Desert?*, Oxford: Elsevier Press, 1975.

Gorman, R. F., ed., *Private Voluntary Organizations as Agents of Development*, Boulder CO: Westview Press, 1984.

Guppy,Nicholas; "Tropical Deforestation: A Global View", *Foreign Affairs* Vol. 62, No.4, Spring, 1984.

Hecht, S.; "Cattle Ranching in the Eastern Amazon: Environmental and Social Implications," *The Dilemma of Amazonian Development*, Emilio Moran (ed.), Boulder: Westview Press, 1983.

Horberry, J. " Environmental Guidelines Survey", International Institute for Environment and Development, 1983, *Environmental Impact of Multialteral Bank-Funded Projects*, Hearings before Subcommittee on International Development Institutions and Finance of the Committee on Banking, Financeand Urban Affairs of the House of Representatrives, pp. 213-251, June 28 and 29, 1983.

Houseal, B., et al, "Indigenous Cultures and Protected Areas in Central America," *Cultural Survival Quarterly*, Vol. 9, no. 1, February 1985.

Inter-American Development Bank,*The Inter-American Development Bank adn the Environment*, Washington D.C.: Inter-American Development Bank, 1983.

International Agricultural Development, "Banking on the Wrong Crops"; "Commodity Survey -Cropping a Better Return", March/April 1985.

International Union for the Conservation of Nature and Natural Resources (IUCN), United Nations Environmental Program (UNEP), World Wildlife Fund, *World Conservation Strategy*, 1980.

Lutzenberger, Jose, statement in Hearings before Subcommittee on Natural Resources, Agriculture Research and Environment of the Committee on Science and Technology, U.S. House of Representatives, 98th Congress, September 19, 1984.

Maier, E.; *La Chinampa Tropical: Una Primera Evaluacion*, Mexico: CECODES, 1979.

Masoni, Vitorio, "Nongovernmental Organizations and Development," *Finance and Development*, September 1985.

Myers, N.; *The Sinking Ark: A New Look at the Problem of Disappearing Species*, New York: Pergamon Press, 1979.

Myers, N.; *The Primary Source: Tropical Forests and Our Future*, New York: Norton, 1984a.

Myers, N., "Genetic Resources in Jeopardy," *Ambio*, Vol. 13, No.3, 1984b.

National Academy of Sciences (NAS), Conservation of Germplasm Resources. Washington D.C.: National Academy of Sciences, 1978.

National Academy of Sciences, Conversion of Tropical Moist Forests, Washington D.C.: NAS, 1980a.

National Academy of Sciences, Research Priorities in Tropical Biology, Washington D.C.: NAS, 1980b.

National Academy of Sciences, Underexploited Tropical Plants with Promising Economic Value, Washington:NAS, 1975.

Nations, J.; and Komer,D.; "Central America's Tropical Rainforests; Positive Steps for Survival), Ambio, Vol. 12, No. 5, 1983.

Norse, E., "Comments on the US Strategy for Conservation of Biological Diversity", in Comments from the Biological Diversity Working Group on the Interagency Task Force Report on the US Strategy on Conserving Biological Diversity, ms., 1985.

Oldfield, M., The Value of Conserving Genetic Diversity, Washington D.C.: Department of the Interior, National Park Service, 1984.

Office of Technology Assessment, Sustaining Tropical Forest Resources: US and International Institutions, Background Paper # 2, Washington D.C.: OTA, 1983.

Pan American Development Foundation, 1984 Annual Report, Washington D.C.: PADF, 1984.

Pearson, C. S., "Down to Business: Multinational Corporations, the Environment and Development," World Resources Institute, Study 2, January 1985.

Pinto, L. Flavio, Carajas, O Ataque ao Coracao da Amazonia, Rio de Janeiro: Editora Marco Zero, 1982.

Posey, D.A.; "Indigenous Ecological Knowledge and Development of the Amazon", The Dilemma of Amazonian Development, Emilio Moran (ed.), Boulder: Westview Press,1984.

Prance, G., "The Increased Importance of Ethnobotany and Underexploited Plants in a Changing Amazon", Change in the Amazon Basin, symposium of the 44th International Congress of Americanists, Manchester U.K., 1982.

Rich, B., "The Multilateral Development Banks, Environmental Policy and the United States", Ecology Law Quarterly, Spring 1985.

Schwartzman, S., "Is Acre's Turn Next?", Defenders, March/April 1985.

Stern, E., "Prospects of Development Financing in the 1980s", American University Law Review, 153, 1982.

Subcommittee on International Development Institutions and Finance of the Committee on Banking, Finance and Urban Affairs, Environmental Impact of Multilateral Development Bank-Funded Projects, Hearings, June 28 and 29, 1983.

Subcommittee on Natural Resources, Agriculture Research and Environment of the Committee on Science and Technology, U.S. House of Representatives, Tropical Forest Development Projects: Status of Environmental and Agricultural Research, Hearing, September 19, 1984.

Tendler, Judith, "Turning Private Voluntary Organizations into Development Agencies: Questions for Evaluation," AID Program Evaluation Discussion Paper No. 12, USAID, 1982.

Treacy, J., "Bora Indian Agroforestry: An Alternative to Deforestation," Cultural Survival Quarterly, Vol. 6, No. 2, Spring 1982.

U.S. AID, "U.S. Strategy on the Conservation of Biological Diversity: An Interagency Task Force Report to Congress", U.S. AID , February 1985.

U.S. Department of State, " The World's Tropical Forests: A Policy, Strategy and Program for the United States", Department of State 1980.

Uquillas, Jorge E., "Indian Land Rights and National Resource Management in the Ecuadorian Amazon", Native Peoples and Economic Development: Six Case Studies from Latin America, Theodore Macdonald (ed.), Cambridge: Cultural Survival Inc., 1985.

Wasserstrom, R., Grassroots Development in Latin America and the Caribbean: Oral Histories of Social Change, New York: Praeger, 1985.

World Bank, Annual Report 1983, Washington D.C.: World Bank 1983.

World Bank, Annual Report 1984, Washington D.C.: World Bank 1984.

World Bank, Forestry Sector Policy Paper, Washington D.C.: World Bank, February 1978.

World Resources Institute, "Tropical Forests: A Call for Action. Report of an International Task Force convened by the

World Resources Institute, the World Bank, and the United Nations Development Program," Washington D.C.: World Resources Institute, 1985.

Contract Paper No. 7

Socioeconomic Considerations for the In-Situ Maintenance of Biological Diversity in Developing Countries

Terry Rambo
East-West Center

October 1985

Office of Technology Assessment
U.S. Congress

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FINAL DRAFT

SOCIO-ECONOMIC CONSIDERATIONS FOR THE IN-SITU MAINTENANCE OF BIOLOGICAL DIVERSITY IN DEVELOPING COUNTRIES

A Report to the Office of Technology Assessment,
Congress of the United States, Project on Assessment
of Technologies to Maintain Biological Diversity
(Contract No. 533-4490.0)

by

A. Terry Rambo

Research Associate
East-West Environment and Policy Institute
Honolulu, Hawaii 96848

October, 1985

ABSTRACT

This report reviews socio-economic considerations for the in-situ maintenance of biological diversity in developing countries. Issues addressed are (1) data required to understand socio-economic issues underlying the loss of biological diversity, (2) data collection methods, (3) data storage, (4) public participation in projects to maintain biological diversity, and (5) problems in enforcing conservation measures. Options for consideration by the U.S. Congress to encourage the use of socio-economic data in formulating U.S. efforts to assist developing countries in maintaining biological diversity are suggested.

1. data requirements: Data requirements can not be specified independently of the conceptual frameworks which will be employed to analyze these data. Four distinct approaches to understanding socio-econmic factors underlying the loss of biological diversity are described and the data requirements of each model set out. No single existing model is adequate for the task and development of more comprehensive conceptual frameworks is a high priority.

2. data collection methods: In addition to standard social science research techniques, several special methods are useful in studying loss of diversity. Those described are rapid rural appraisal, household record keeping on local resource exploitation, and ethnoecology research.

3. data storage: Developing technologies to make document collections and data banks in the U.S. more readily accessible to scientists in the developing countries presents a major problem with regard to data storage.

4. public participation: Creation of a favorable climate of public opinion for conservation measures and establishing mechanisms to obtain maximum participation of rural people in the design and implementation of projects to maintain biological diversity are discussed. The need for better understanding of rural social organization as it effects resource management is examined.

5. problems in enforcing conservation measures. Assignment of clear responsibility for management of natural resources and the imbalance between the means devoted to enforcement of conservation measures and the market value of the resources in protected areas are seen as critical issues.

6. options for consideration by the U.S. Congress include promotion of more high quality socio-economic research on the loss of biological diversity, increasing the involvement of developing country social scientists in research relating to maintenance of biological diversity, and enhancing the ability of U.S. agencies working in developing countries to employ socio-economic information.

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INTRODUCTION

In support of the Office of Technology Assessment's project on "Technologies to Maintain Biological Diversity," this paper reviews socio-economic considerations for the in-situ maintenance of biological diversity in developing countries. For purposes of this paper, "socio-economic considerations" are taken to include all aspects of human social systems, including population patterns, social and political organization, economics, cultural norms and values, ideology, and knowledge and belief systems, that may influence exploitation and management of natural resources.

This paper is divided into six major sections: 1) data requirements, 2) data collection methods, 3) data storage, 4) public participation in projects to maintain biological diversity, 5) problems in enforcing conservation measures, and 6) options for consideration by the U.S. Congress.

1. DATA REQUIREMENTS

In order to discuss the kinds of data needed to understand the socio-economic issues underlying the loss of biological diversity in developing countries it is necessary to first specify the conceptual frameworks or models that will be employed to analyze these data. Such frameworks set forth the probable linkages between social and ecological variables of concern. Unfortunately, social scientists have paid little attention to the loss of biological diversity and have yet to formulate explicit models for conceptualizing this issue. At least four quite different approaches have been implicitly suggested in the literature on species loss. These may be referred to as (a) the population pressure model, (b) the cultural values model, (c) the political economy model, and (d) the niche model. Each of these models emphasizes different social factors as causal in loss of biological diversity and each requires different kinds of data to be useful. Although none provides a completely adequate explanation for the problem under discussion, each does offer useful insights for future analysis.

a) The population pressure model. Resource degradation is attributed in this model to the 20th century population explosion in the developing countries. As a recent World Resources Institute report (1984: 8) puts it, "pressed by economic, social, and political factors, the rural poor in developing countries are forced to overexploit their environment simply to survive." Hunger, rather than economic greed or cultural attitudes of dominance over nature, is seen as forcing desperate people to act in ways that cause loss of diversity.

Certainly, population pressure contributes to the deforestation now occurring in tropical countries. The last remaining rain forest on Negros Island in the Philippines is being converted to farm plots by impoverished squatters unable to find land in the densely populated lowlands (Abregana 1983). Similarly, in Central America the forests of the Peten and southern Belize are rapidly falling to the axes of Maya Indians who have migrated from the overpopulated Guatemalan highlands in search of their own farm plots (Rambo: personal observation).

The need of the poor for food, fuel, and other resources also contributes to extinction of wild species in areas of long-term dense settlement. Wild birds have virtually vanished from rural areas in the Philippines because of intense hunting pressure. The author will never forget watching impoverished refugees in wartime Saigon, Viet-Nam, chipping off the bark of shade trees lining that city's streets in order to get fuel to cook their meager meals.

In many developing countries, however, deforestation and destruction of wildlife result as much or more from deliberate national economic development projects as from survival activities of the poor. The conversion of rainforests to rubber and oil palm plantations in Malaysia is motivated by the national need to generate foreign exchange from export crops (Aiken and Leigh 1985). In China, the Cultural Revolution policy of treating "grain as the key link" led to considerable conversion of forests to agricultural use. Every locality in the country, regardless of resource endowment, was expected to achieve self-sufficiency in grain production (Smil 1984).

Much of the destruction of natural resources blamed on the rural poor is actually caused by outside entrepreneurs. In Northeast Thailand, for example, squatters clearing forest in the Non Perm dam watershed are employed by wealthy Thais from Bangkok who seek to turn the area into sugar plantations (Rambo: personal observation). Destructive swidden farming along new roads in Kalimantan, although officially blamed on indigenous tribal groups, is actually the work of urban based market gardeners (Dove: n.d.) Destruction of the reefs around Negros Island in the Philippines by fishermen using dynamite is encouraged by commercial dealers from Manila (Angel Alcala: personal communication). It has also been recognized that much of the cutting of fuelwood in rural areas is for sale to urban users rather than to meet local needs.

Although the population pressure model does not explain all loss of diversity, it does direct attention to the linkage between human needs and environmental exploitation. Understanding the ways in which population pressure affects biological diversity requires detailed data on resource needs and resource exploitation patterns of particular communities in specific local ecosystems. Key questions include what kinds and quantities of resources are used? Where are needed resources obtained and what sorts of substitutions are acceptible? How do changes in prices of resources affect use of alternative commodities?

b) The cultural values model. In this model, destruction of natural resources is linked to the loss of traditional non-Western cultural values emphasizing man's obligation to live in harmony with nature and to their replacement by the modern Western ethos of human dominance over nature (White 1967; Reich 1970). The underlying assumption is that non-Western cultures are inherently conservationist, being guided by beliefs, values, and practices, often religious in character, that serve to maintain ecosystem homeostasis and species diversity.

The literature of ecological anthropology is replete with case studies illustrating this point of view. Roy Rappaport's (1968) monograph, Pigs for the Ancestors, for example, asserts that the ritual cycle of the Tsembaga tribe of Papua New Guinea regulates warfare and pig slaughter so as to keep the human population within the carrying capacity of its ecosystem. A recent paper by Pei Shengji (n.d.) reports that animistic religious beliefs of the Dai National Minority in Xishuangbanna Prefecture, Yunnan Province, China, result in maintenance of between 1.5 and 2.5 percent (30-50,000 ha) of the surface area of the prefecture as naturally forested "holy hills." According to Pei,

> the Holy Hill is a kind of natural conservation area founded with the help of the gods; all animals, plants, land, and sources of water within it being inviolable. Gathering, hunting, wood-chopping, and cultivating are strictly prohibited activities.

A thorough literature search would turn up many more examples of ways in which cultural values contribute to the preservation of ecological diversity. It is questionable, however, if one can generalize from such specific examples to the universal principle that all traditional societies are conservationist in practice. Rambo (n.d.) has shown that the Semang aborigines of Peninsular Malaysia are not inhibited by cultural values in their exploitation of forest resources. It is only their small numbers and limited technology that restrict their impact on the rainforest ecosystem. Tuan Yi-fu (1968) has also pointed out that traditional Chinese society produced massive environmental degradation, despite formal adherence to Confucian values of living in harmony with nature, simply because of the country's vast human population and the scale of productive activities needed for its support. As the last case suggests, the cultural values model should not be employed without also taking the population pressure model into consideration.

Cultural values can also work against conservation of particular "disvalued" species. The well-founded fear of tigers in Asia, and the less well-founded fear of wolves in North America, lead humans to kill these animals on sight. Assignment of ritual value to species may also lead to their over exploitation. The high value placed on rhinoceros horn in Chinese medicine has resulted in astronomical prices being paid for these horns making conservation basically impossible in poor rural areas.

The cultural values model directs attention to the search for specific knowledge, beliefs and values that may influence human behavior in ways that affect maintenance of biological diversity. Ethnoecological research (Fowler 1977) is needed to understand how people in different cultures conceptualize the natural world. There is a large body of research demonstrating that different cultures have different ways of dividing up and labeling natural diversity. Conklin's (1955) pioneering ethnoecological research on the Hanunoo of Mindoro Island in the Philippines revealed that this group of shifting cultivators identified several hundred more named "species" in the rain forest flora than did scientific botanists classifying the identical collection of plants. Whether or not people culturally recognize the existence of a species has an important bearing on their behavior towards it.

Ideally, as Dunn (1975) points out, ethnoecology should not be concerned with merely compiling taxonomic lists; it should also describe folk knowledge about the functioning of the ecosystem and its individual components. As keen observers who spend their lives in a particular environment, indigenous people often have ecological knowledge, particularly about long term population variability, that scientists can obtain only with great difficulty. It should also be recognized, especially with regard to the uses and characteristics of traditional cultivars, that folk knowledge is as significant a resource as the genetic material itself. Preserving these species in genetic banks without ensuring adequate cultural documentation loses much of their potential value.

In addition to ethnographic studies of folk ecology, the cultural values model also requires survey research at the societal level to collect data on people's environmental knowledge, attitudes, and values. Ideally, such information should be collected from samples stratified not only by region, but also by age, sex, class, and other key social variables. A recent pilot study conducted by the Indonesian Ministry of State for Population and Environment (KLH) offers an example of such a survey research based approach (Dahlan et al 1985). Samples of villagers in communities representing different levels of economic development in the Lebak District of West Java were interviewed using a standardized questionnaire to ascertain their environmental concerns and their views on what measures should be taken to solve perceived environmental problems. A cross-culturally valid instrument for eliciting cultural values related to the use and conservation of the environment was also administered. KLH is in the process of expanding this survey to other areas in Indonesia to provide the basis for designing a national strategy to improve communication between the government and the rural population about resource management.

c) The political economy model. This model attributes destruction of natural resources and loss of species in developing countries to the inferior structural position which these "peripheral" countries occupy in the global economy. It suggests that their resources are exploited to meet the demands of the capitalist core countries. Decisionmaking about resource management is claimed to be in the hands of large and powerful foreign corporations which are able to operate essentially outside the control of indigenous legal and administrative systems.

Certainly there are clearcut historical examples of natural resource destruction that appear to fit this model. Sandlewood was brought to the brink of extinction in the Hawaiian Kingdom as a consequence of foreign demand much as the beaver was endangered by overtrapping to supply the European hat makers during the peak period of the North American fur trade. Both cases illustrate how mismanagement of natural resources in peripheral areas can result from their economic and political subordination to the capitalist core areas. The Jari River scheme in the Amazon, in which a vast expanse of rainforest was destroyed as part of a single foreign entrepreneur's pursuit of profit, also appears to fit the political economy model. It has also been charged that deforestation in Central America is caused by the expansion of ranches to provide cheap beef for the U.S. fast food market as part of the the "hamburger connection" (Nations and Komer 1983).

It now appears, however, that the "hamburger connection" is more complex than is posited by the political economy model. Most beef cattle raised in Central America are consumed locally rather than exported to American fast food chains. It is increased internal demand for fresh meat, a demand reflecting local economic development and the growth of an indigenous middle class, that provides the driving force for conversion of tropical rain forests to pastures (Nations 1985). As this case suggests, the political economy model must take into account not just the influence of external forces in resource exploitation but also look at forces internal to developing country societies. One needs to know the class structure of the society and the interests, often contradictory, of each class in resource use and management.

In some developing countries there may be essentially a one-to-one correspondence between elite status and the power to destroy natural resources at will. In most countries, however, members of the elite have competing or contradictory interests regarding the exploitation of natural resources. This is illustrated by the controversy in Malaysia in the late 1970s over logging of the Endau-Rompin forest. In this case the State of Pahang sold logging concessions in an area designated by the Federal government as a future national park. The federal authorities permitted the usually highly controlled press to publish articles and letters from the public protesting the logging. A major contradiction between the interests of the central authorities, who seek to conserve some forests both for technical land and water management reasons and as potential tourist attractions, and the interests of local political elites, who are concerned primarily with short-term economic gains, was given public recognition.

In situations like that just described, data requirements are complex and collection of reliable data problematic. Detailed mapping of the social, economic, and political alliance structure of the society is required. Relationships are often covert and accurate information virtually impossible to obtain. In the Malaysian case, for example, foreign press reports claimed that the Sultan of Pahang profited from sale of the Endau-Rompin logging concessions but the Malaysian press was not permitted to publish these allegations. Similar allegations of profitable involvement of leading political figures in illegal logging are the subject of popular rumor in Indonesia and the Philippines.

d) The niche model. In this model, survival or loss of species is seen as reflecting the specific niche that each occupies in the human ecosystem. Rerkasem and Rerkasem (1984) have shown, for example, how more than 40 traditional rice varieties have persisted in the Chiang Mai Valley in Northern Thailand, despite government attempts to introduce modern high yielding varieties. Each traditional cultivar fills a distinctive "agroecological niche" the parameters of which are defined according to both biophysical factors (tolerance to deep water, production of straw), and socio-economic factors (matching of length of growing period with availablility of farm labor, taste preferences). A traditional variety is likely to be displaced only in those cases where the new higher yielding variety fits most of the important parameters of the niche occupied by the former.

Although proposed by the Rerkasems to explain survival of diversity in cultivated crop varieties, the niche model may also be profitably employed to understand survival or extinction of wild species. For example, species to which great symbolic value is attached, e.g., the Bald Eagle in the United States, the Monkey-eating Eagle in the Philippines, and the Giant Panda in China, may attract conservation efforts disproportionate to their total numbers or ecological significance. In contrast, species whose human ecological niche lacks symbolic importance, e.g., the snail darter fish, may not generate the emotions needed to support sustained conservation efforts. Demonstration that an otherwise unvalued species contributes to the survival of other, highly valued species may also provide an effective motivation for conservation. In Malaysia, public opinion was marshalled to protect the Batu Caves from quarrying by pointing out that the durian crop was dependent for pollination on cave nesting bats. It would have been difficult to win public support for preserving bats or their nesting sites without linking their survival to continued production of this highly valued fruit.

Delineation of the human ecological niche of a species may also lead to increased pressures to eliminate it, as has happened in the cases of species found to endanger human health. Even dedicated conservationists are unlikely to call for maintaining diversity of malaria-carrying Anopheles mosquito populations. Efforts to eliminate such vectors frequently threaten the survival of whole ecosystems, as happens when swampy areas are drained to destroy mosquito breeding habitats. Similarly, the dependence of the sleeping sickness carrying tsetse fly on brushy areas has created pressure to clear natural vegetation in areas of Africa infested with this disease.

Effective use of the niche model requires a very detailed data about the interaction of individual species with human populations. The painstaking collection of such data is most effectively done by scientists residing in developing countries. The difficulty of doing this research is further increased because it requires cooperation between natural and social scientists. Few developing country institutions offer a favorable setting for such work. A noteworthy exception is the Padjadjaran University Institute of Ecology in Bandung, Indonesia, which has, with financial support from the Ford Foundation, engaged in systematic research on traditional home gardens for more than a decade. The role of these gardens in maintaining biological diversity by providing suitable niches for many plant and animal species, has been a major concern of this work (Soemarwoto and Soemarwoto 1984).

As the preceding discussion of socio-economic considerations in the maintenance and loss of biological diversity has shown, none of the four existing models is sufficiently comprehensive to explain all cases of species loss in the developing countries. Population pressure accounts for some loss of diversity, but commercial exploitation explains other cases. Changes in cultural values may permit destructive behavior towards previously protected resources in some situations; in others, changes in niche parameters may lead to displacement of one species by another with no alteration in human values. In many, perhaps most cases, multiple, often conflicting, social and economic factors are operative so that single factor models can not adequately explain species loss. The real world is so complex that simple conceptual frameworks can not adequately model its dynamics. Much more attention needs to be paid to formulating more comprehensive causal models. Only then can data requirements and data collection methods be fully specified.

2. DATA COLLECTION METHODS

In view of the extremely wide range of data needed to understand socio-economic issues underlying the loss of biological diversity, it is impossible to meaningfully review all appropriate data collection methodologies in a paper of this length. Many of these (e.g., survey research; media content analysis) are standard methodologies in the social sciences and are adequately described in the literature pertaining to these disciplines. Attention will be given here to specialized techniques for collecting information on local level resource exploitation such as a) rapid rural appraisal, b) household record keeping, and c) ethnoecology.

a) rapid rural appraisal. Rapid rural appraisal (RRA) or, as it is also sometimes known, SONDEO or rapid reconnaissance, has been advanced as a technique for "quick and clean" data collection on rural development and resource management (Chambers 1983, Grandstaff and Grandstaff 1985). The technique is intended to circumvent the deficiencies both of slow, poorly focused, and expensive questionnaire surveys ("long and dirty") and of the short, and often misleading, "quick and dirty" observation visits made by outside experts to rural areas that Chambers (1979) has labelled as "roadside development tourism".

The most productive approach to RRA is for an interdisciplinary team of natural and social scientists to conduct semi-structured interviews with key informants to elicit their thinking about specific resource management issues. Informants may be selected according to their probable knowledge of the topic being studied (e.g., if the concern is with wildlife one might interview individuals known to be good hunters) or in order to counter the selection biases in favor of the rich and powerful which characterize many observation visits (Chambers 1979). Although no questionnaires are used, the RRA team may employ an informal interview guide which lists the main topics to be covered in the interviews. It is important to retain sufficient flexibility to be able to further develop unexpected new leads that may open up in the course of the questioning. This is also why interviews should be done by interdisciplinary teams since only a specialist in a particular field is likely to recognize the significance of new, and often unanticipated, information relating to that speciality.

Although RRA is proving to be a very productive technique for collecting data on problems of rural resource management it is no panacea. When done by experts it can be remarkably effective but when done by individuals lacking full professional knowledge and maturity it may generate findings of even less value than those resulting from poorly conceived conventional survey research. It is also important to recognize that RRA is an a-theoretical data collection technique: It suggests how to ask questions, it does not offer any guidelines about what questions one should ask.

b) household record keeping. Although required for use with the population pressure model, relatively few detailed analyses have been published of the total pattern, both spatial and temporal, of ecosystem exploitation by specific local communities. In part this reflects the lack of suitable methodologies for such research. One very productive, but also very labor intensive, method for collecting such data is the technique of household record keeping. In this approach, a sample of households is interviewed on a regular schedule to determine the kinds, quantities, and sources of natural resources used in the preceding 24 hours. Using this method, Zainuddin (1977) was able to determine the number of forest animals killed by hunters from a sample of Proto-Malay households. Other studies have focused on use of fuelwood and other biological energy sources by rural households (Bialy 1982). Grossman (1984) presents a useful survey of collecting time-use data in developing countries.

c) ethnoecology research. Techniques for eliciting ethnoecological information are generally quite labor intensive, often requiring the scientist to undertake prolonged participation-observation research. Conklin, for example, devoted 18 months to his study of Hanunoo ethnobotany. Much of his time was spent accompanying informants on gathering trips into the rainforest so that they could identify plant species in their natural habitat. In the study of the agroecological niches occupied by traditional rice varieties in Chiang Mai, the investigators visited a large number of fields with the farmers and asked them to explain why they had decided to plant particular varieties in each specific situation (Rerkasem and Rerkasem 1984). In the Institute of Ecology's home garden research, farmers were also asked to explain why specific varieties were planted in specific places within their garden plots. Light tolerance was a frequent response and subsequent experimental work demonstrated that there was a close correspondence between farmer assessment of this niche parameter and the scientists' empirical measurement of the photosynthetic requirements of the different varieties (Christanty and Priyono 1979).

To increase ethnoecology research efficiency, Dunn (1975) successfully experimented with use of skins of mammals from a museum collection to elicit species identification from his Temuan informants, thus avoiding the need for spending prolonged periods in the rain forest waiting to encounter rare and elusive species. Rapid rural appraisal methods can also be used to collect certain kinds of folk ecological knowledge as has been demonstrated by the Khon Kaen University study (1984) on the functions of trees in the rice paddies of Northeast Thailand. As with all RRA research, however, it is necessary for the investigators to begin their field work with at least some idea of which social and ecological relationships have significance in the survival of the species being studied.

3. DATA STORAGE

The data requirements for understanding socio-economic considerations in the loss of biological diversity in the developing countries are virtually coterminous with the totality of social science and human ecology research. Because of the extremely wide range of information needed for such analyses, establishment of special purpose collections or storage centers, such as the "conservation data centers" advocated by the World Resources Institute (1984: 30-31), does not appear practical with regard to socio-economic data. Greater returns might be expected from efforts to make existing general purpose data collections more accessible to developing country researchers.

Locating needed information is a time consuming and often frustrating task. No single library, especially in the developing countries, is likely to have all relevant documents in its collection. Development of computerized data bases and, more importantly, finding ways to make these accessible to researchers in developing countries, might help to solve some of these problems of data storage and retrieval.

Because information on natural resource management often has political implications, many of the most important documents, particularly those originating in government agencies, have a very restricted circulation. U.S. diplomatic and aid missions often possess valuable data relevant to the political economy model but such information is not generally available to non-government analysts. It is also important to recognize that scholars working in many developing countries must be extremely cautious about what they say in print, a fact that lessens the value of many published reports.

4. PUBLIC PARTICIPATION IN PROJECTS TO MAINTAIN BIOLOGICAL DIVERSITY

Assuming that a society is anything less than totally authoritarian, some degree of public participation is needed to design and implement successful projects to conserve biological diversity. Obtaining effective public participation has two major aspects: a) creation of a favorable climate of public opinion in support of conservation, b) involving rural people in designing and implementing conservation activities.

a. creation of a favorable climate of public opinion. To the extent that resource exploitation is governed by essentially rationalistic criteria, in particular the perceived self-interest of various individuals or groups, e.g., rural people, local and national elites, and multinational corporations, behavior affecting maintenance of species diversity may be changed by providing new information that alters their perception of what behavior is in their self-interest. Convincing people in the developing countries that maintaining biological diversity is an important problem that they should want to do something about is a critical step in developing successful conservation programs. Unless a strong climate of public opinion is created in favor of such programs, it is unlikely that political leaders and development planners will assign them the priority they deserve, particularly in situations where the short term economic interests of powerful individuals or groups are threatened.

Much of the current international effort to preserve biological diversity in the developing countries appears to be aimed at influencing public opinion. Scientists and environmental activitists are trying to bring the biological diversity issue to public attention and to convince policymakers that action is urgently required to solve this problem. Calls for an international conference on preservation of biological diversity (World Resources Institute 1984) are representative of this approach. Although the Stockholm Conference did succeed in drawing public attention to the state of the environment as a legitimate international concern, it is doubtful, given the multitude of critical issues presently competing for public attention, that a conference on maintaining biological diversity will produce dramatic results. It should also be recognized that, as was demonstrated by the Bucharest population conference and, to a lesser extent Stockholm, international conferences can lead to polarization of opinion as readily as its unification. Given the fact that many developing country political leaders and intellectuals perceive concern with conservation of genetic resources as simply another First World plot to impede their economic development, or to use them as cheap storehouses of genetic resources for future exploitation by the developed economies, a world conference at this time might do as much harm as good.

Increased emphasis on environmental education within the developing countries is another strategy for changing public opinion. The need for such education is based upon the assumption that most people in the developing countries are ecological illiterates who do not understand the long-term consequences of human misuse of natural resources. It is certainly true that ecology does not form a major component of the school curricula in most countries and the ability of even well-educated laymen to comprehend complex analyses of environmental issues is correspondingly limited. Urban dwellers, which includes most developing country government policymakers, have, as the World Resource Institute (1984: 68) points out, "simply become so far out of touch with the natural world that they rarely make the connection between the necessities of everyday existence and the origin of many of these necessities in the natural world." On the other hand, many rural people, particularly members of groups that have been living in the same habitat for generations, often have an excellent applied understanding of ecology even though they lack any formal education in the subject. In such a situation, introduction of environmental education into primary school curricula may have less urgency than its incorporation in secondary and tertiary programs where it is most likely to influence the thinking of future policymakers and opinion leaders.

A major constraint on implementing environmental education programs at all school levels in developing countries is the shortage of appropriate teaching materials in local languages (World Resources Institute 1984: 65). Most textbooks use examples drawn from temperate zone ecosystems which are difficult for students in the tropics to understand or to relate to their own situations. Encouraging developing country scientists to produce locally relevant teaching materials might help overcome this limitation. Non-governmental environmental groups such as the Malayan Nature Society make a major contribution by publication of natural history guidebooks and other locally oriented environmental materials. Such publications are useful not only in school curricula but also in continuing informal education programs directed at the general public.

Mobilization of public support for preservation of biological diversity through mass information campaigns has met with considerable success in some developing countries. In the People's Republic of China, a national ecological society has been established under the sponsorship of the Environmental Protection Agency to disseminate scientific knowledge about resource management to the public. In Malaysia, numerous voluntary organizations such as the Malayan Nature Society, the Friends of the Earth, and the Consumers' Association of Penang, conduct extensive informational programs intended to develop public understanding of the need to maintain biological diversity (Aiken and Leigh 1985).

The effectiveness of efforts to mobilize public opinion are likely to vary according to the national social and political context in which they are attempted. Authoritarian regimes, in which members of the ruling elite have personal interests in exploitation of natural resources, are unlikely to encourage or even permit campaigns to mobilize public opinion in favor of resource conservation. In such countries, environmental activism may become a surrogate form of political struggle as happened in Thailand in the early 1970s and is the case in the Philippines today. In such contexts, foreign involvement, however well intended, may be viewed with deep suspicion as having political rather than scientific objectives. Even in more open societies, however, it should not be assumed that simply informing people of the threat of loss of biological diversity will be sufficient to ensure support for conservation programs. Such projects almost always have differential impact on the status and wellbeing of different social classes and groups. As Romm (1982) observes in his analysis of social forestry projects, unless such concerns are addressed in the project planning process, unanticipated resistance is likely to emerge.

Detailed analyses of the costs and benefits of in-situ efforts to maintain biological diversity may help to overcome suspicions within developing countries of the motivations behind such programs. It is important that such analyses deal not just with net gains to GNP but also examine the distribution of costs and benefits between different social sectors. As Tisdell (1983) points out, benefits generated for the national economy by international tourism to conservation areas may not actually reach the local population whose livelihood is affected by establishment of parks or nature reserves. In fact, the local population may actually suffer substantial losses due to inflation of prices resulting from tourism and the loss of access to traditional resources enclosed in the reserves. It is also important to assess the share of economic benefits accruing to foreign, and especially developed country, interests. One of the major criticisms directed at Malaysia's national park program was that the parks constituted a playground for affluent foreign tourists but were of little use to the nation's poor. Encouragement of *in-situ* preservation of traditional crop cultivars has also been attacked as serving the interests of foreign plant breeders and seed producers.

b) *involving rural people in project design and implementation*. In planning natural resource conservation projects it is vital to recognize that in developing countries there are virtually no ecosystems that do not already have human populations participating actively in their management. Even what may appear to the casual observer to be pristine natural systems are often the outcome of extended interactions with indigenous human populations. The grasslands of North America (Stewart 1955), the scrublands of Australia (Hallam 1975), and even the rainforests of Malaysia (Rambo 1979), have all been influenced by manipulation by aboriginal peoples. In designing projects to conserve these ecosystems it is essential to take the presence of human populations into account and, even more important, to enlist their participation in project planning and implementation.

A major obstacle to participatory projects is the negative attitude that many scientists and government officials have towards rural people (Jamieson 1984). As Dove (n.d.) has argued to be the case in Indonesia, members of the urban elite often view rural people, particularly members of minority tribal groups, as backward, stupid, and bound by their "superstitious" cultural traditions to wasteful and destructive use of natural resources. For example, farmers practising swidden agriculture are almost universally criticised by foresters and development planners, even though such systems have been shown to produce maximum returns for minimum labor inputs (Rambo 1984b) and may often be the only system suitable to local conditions (Dove 1983). When such views of rural people prevail, convincing scientists and officials to involve them in the planning of conservation projects represents a real problem.

Changing elite attitudes towards rural populations is extremely difficult and there are few wholly successful examples of efforts to do so. Hundreds of thousands of scientists, students, and cadre were sent to the countryside to learn from the peasants during China's Cultural Revolution but most observers consider the program a failure. Indonesia requires all university graduates to spend several months living in rural villages. The graduates are perceived as teaching modern ideas to the peasants rather than learning from them, however, and the experience does not appear to produce a favorable shift in attitudes (Dove n.d.). Perhaps more successful was the "indigenismo" movement associated with the Mexican revolution in which, for nationalistic reasons, a concious effort was made to raise the cultural status assigned to the country's Indian minority. It may be significant that research on traditional agroecosystems, such as the chinampas, still receives strong official support as providing an ecologically sustainable basis for modern agricultural development of the tropical parts of Mexico.

Even in those cases where scientists and policymakers are genuinely ready and willing to take folk knowledge of ecosystems into serious account, there remain major difficulties in communication between those holding this knowledge and those seeking to understand it. The cognized ecosystem models of scientists and traditional farmers are not identical. They employ different classificatory principles and include somewhat different parts of the total real world environment.

Figure 1a is a schematic illustration of a "real" ecosystem. It includes every element and every interaction that is actually occurring in nature. Figure 1b represents the folk model of the same system. Note that many areas included within the real system are not included within the model employed by the traditional villagers. For example, the existence of microorganisms is unknown, indeed unknowable, to human observers lacking microscopes. Note also that Figure 1b includes phenomena that modern scientists do not believe even exist. For example, cultures that have an animistic religion include the spirits of rocks, waterfalls, and trees in their ecosystem model and belief in the presence of these spirits influences human behavior towards the environment. Figure 1c represents the modern scientific model of the same real ecosystem displayed in Figure 1a. Note that the scientific model incorporates much more of the real system than does the folk model, reflecting in large part the superior observational tools and techniques available to modern scientists. Note also, however, that the scientific model does not display total fidelity to the real ecosystem. There are aspects that are omitted, sometimes even aspects that are included in the folk model. There are also aspects included in the scientific model that have no empirical reality and yet are believed to exist by the scientist with as much confidence as the animist has in the existence of nature spirits. Colinvaux (1973) presents a sobering review of the extent to which scientific ecology has pursued non-existent phenomena.

The fundamental problem in employing folk ecological knowledge as an intellectual resource in designing conservation programs is that it requires the conversion of data collected by persons using one paradigm into a form intelligible by users of a wholly different paradigm. The problem is fully as difficult as that of translating classical Chinese poetry into English. It is possible to do the job, as Richards (1984) has demonstrated in his work relating traditional African agroecological knowledge to modern farming systems research, but it requires a researcher of great patience and cultural sensitivity. In most situations it also means a greatly lengthened project design and planning phase because there are few shortcut methods for developing an understanding of folk ecology (see Section 2c).

At least as difficult as incorporating local knowledge into the design of conservation projects is the problem of organizing projects in ways that are compatible with existing rural social structure. Urban based elites in most developing countries have a genuine lack of understanding of how their own rural societies are organized and how this organization influences resource management. Such ignorance is often concealed by official rhetoric emphasizing national unity and the sharing of a common national culture. Not surprisingly, social scientists who specialize in studying traditional rural societies, especially when they are foreigners, generate considerable resentment when they point out situations where policymakers and development agents have misunderstood the local social system. The offending foreign scientist may be punished by official denial of continued access to research sites; punishment of local scientists may take more severe forms.

One of the most common sources of such misunderstanding in designing natural resource conservation projects is the "myth of primitive communism." This is an assumption prevalent among planners in developing countries that, because rural people live in close knit communities, they inevitably practise community ownership and management of natural resources (Dove 1982). As numerous studies by anthropologists have shown, each society has its own unique pattern of organization and true communal management is the exception rather than the norm. Attempts to impose communal management systems on resources that are actually partitioned between different social groups are likely to fail (Romm 1982).

Even when planners recognize their need for more accurate and detailed information on rural societies and their relations with the environment, obtaining such information is not simple or easy. "Roadside development tourism" (Chambers 1979) is easy to criticise but hard to replace with better alternatives. The frequently heard call to involve villagers in the planning process begs the question of which villagers representing which special interests within the community. Working with officially recognized leaders often limits participation to only those residents aligned with the faction holding power. In societies organized along caste or ethnic group lines, members of socially inferior groups may be denied any involvement in decisionmaking, even though it is their access to resources that may be most threatened by conservation projects (Ramm 1982).

Recognition that the problem of ensuring genuine popular participation is truely and legitimately complex, and one that allows no easy "off the shelf" solutions, may be the first important step towards making progess. What is needed at this stage is encouragement for experimentation with a wide variety of approaches and careful documentation and analysis of the results of these experiments. The kind of analysis represented in a recent report on the Kalihan Educational Foundation's upland development project in the Philippines (Barker 1984) needs to be replicated many times over before a useful set of guidelines on ensuring community participation in planning and implementation of projects to preserve biological diversity can be compiled.

5. PROBLEMS IN ENFORCING CONSERVATION MEASURES

Two of the most important socio-economic considerations in enforcement of conservation measures in developing countries are (a) assignment of management responsibility and (b) ensuring a proper balance between the means devoted to conservation enforcement and the value of the protected resources.

a) assignment of management responsibility. In the Philippines responsibility for management of all lands having a slope in excess of 18 percent is assigned by law to the Bureau of Forest Development (BFD). Administrative responsibility for all upland ecosystems is thus rather neatly placed in the hands of a single national forestry agency. Unfortunately, however, large areas within this jurisdiction are not covered by forest but are instead in agricultural use. In some cases, this is the result of recent migration of lowland farmers who have illegally cleared plots in protected areas. In many other cases, however, such as the Bontoc and Ifugao tribes in the Cordillera, areas that have been exploited by indigenous peoples for thousands of years have been placed under BFD's control. Technically, the native inhabitants have been converted into illegal squatters. The result has been to confuse rather than clarify the question of who is responsible for managing upland resources. "Squatters" lacking secure tenure are unwilling to make the capital investments necessary to ensure longterm resource conservation yet the BFD lacks the means to adequately protect the vast area under its technical control. The government response has been to introduce a bewildering array of ad hoc administrative solutions: Temporary occupancy licenses, forest leases, and ancestral land right claims have been thrown like a crazy quilt over the uplands (see Castro, 1984, for a comprehensive treatment of this complex case). In such a situation, which is the norm rather than the exception in the developing countries, enforcement of conservation measures is exceedingly difficult if not impossible.

As the Philippine case suggests, there are several distinct issues involved in the delineation of responsibility for managing resources: (i) communal versus individual responsibility, (ii) centralized versus decentralized control, and (iii) sectoral versus areal administrative agencies.

(i). communal versus individual responsibility: Accompanying the common elite misperception of traditional villagers as "primitive communists" (see section 2b), is the belief that communal systems of resource conservation are inherently well suited to village conditions. This is particularly ironic since many of the most visible examples of degradation of the environment in developing countries are to be found on lands already under communal control. Thus, the emphasis in India's social forestry program has been on establishing "community forests" or "village woodlots" in precisely those situations where existing degradation of the common lands indicates that the community lacks internal management institutions adequate to the task of controlling exploitation of corporately held resources (Romm 1982). The frequent lack of success of upland reforestation efforts in the People's Republic of China has also been attributed to lack of effective institutional mechanisms to control access to communally-owned resources (Smil 1984). Under the current "responsibility system" reforms, individual households are being given authority to manage forest plots.

That the "tragedy of the commons" (Hardin 1968) represents a real problem does not, however, mean that the only suitable solution is private ownership or control as the Chinese are proposing. This is particularly the case where the objective is to preserve whole ecosystems which are not amenable to subdivision into individual management units. As Runge (1983) points out, Hardin failed to distinguish between situations allowing individuals unregulated free and open access to resources and those situations where traditional social institutions exert control over individual exploitation of common property. As Pei (n.d.) shows in his description of the "holy hills" of the Dai people in Southwest China, shared religious beliefs can effectively control individual use of common lands. Similarly, Brett (n.d.) describes how the ritual system of the Bontoc of Northern Luzon, Philippines, contributes to equitable sharing of common property irrigation water. Our understanding of the relationship between property rights and resource management is still rudimentary but there is a growing interest in research on this key problem as is exemplified by the formation by the National Research Council's Board of Science and Technology for International Development of a Common Property Resource Management Network.

(ii). centralized versus decentralized management: Developing countries have generally opted for highly centralized administrative systems with decisionmaking authority regarding resource management tightly held in the hands of the central government. Powers of lower level units (states or provinces, districts and villages) are correspondingly limited. The advantage of the centralized approach is that it permits rapid decisionmaking and uniform application of conservation measures throughout a whole country. Disadvantages include the difficulty of adapting centrally decreed programs to the often unique situations of lower level units and the "adminstrative fade" that occurs between the capital and the more remote parts of the country. Especially troublesome, as the Philippine upland management experience indicates, are relations between the central authority and ethnic minorities having their own distinctive cultural values and resource management objectives.

(iii). sectoral versus areal agencies: In many developing countries, responsibility for resource conservation is split between several different agencies organized along sectoral lines, e.g., agriculture, forestry, wildlife, etc. Protection of critical ecosystems must be organized along geographic lines, however, which often leads to overlapping or competing jurisdictional claims between sectoral agencies. Again, the case of the Philippine uplands nicely illustrates the problem. The Bureau of Forest Development is asigned responsibility for administering an area which in reality includes a great deal of agricultural activity which BFD is technically poorly prepared to manage. Mining and exploitation of energy resources also occur within the uplands but these activities are under the jurisdiction of other agencies and are specifically excluded from BFD control. Uniform enforcement of conservation policies is unlikely under such circumstances.

An alternative approach is to place management of protected areas in the hands of a special purpose agency such as the U.S. National Park Service. In developing countries, however, such areal agencies are generally bureaucratically weak and lack the power to compete for needed resources with the long-established, production oriented sectoral agencies.

b. balance between means devoted to conservation and resource values. In most developing countries there is a vast imbalance between the means devoted to conservation enforcement and the market value of protected resources. Salaries of officials assigned to enforce conservation measures are exceedingly low in comparison to the worth of the resources they are supposed to protect. The potential for corruption in such situations is, not surprizingly, high.

An obvious remedy, but one rarely tried, is to pay those charged with policing protected areas sufficiently high salaries so that they are less likely to be tempted by bribes. Few developing countries have sufficient means to do this and in any case it can create major imbalances between government and private sector salaries. Using non-monetary incentives, e.g., development of a professional esprit de corps, giving public recognition to effective task performance, etc., is an alternative. In situations where public opinion strongly supports conservation measures, finding ways to make enforcement officials more accountable to the local population may place them under pressure to perform effectively. Non-govermmental environmental groups may play an important monitoring function in this regard.

6. SOME OPTIONS FOR CONSIDERATION BY THE U.S. CONGRESS

Given the complexities of using socio-economic data in formulating U.S. efforts to assist developing countries in maintaining biological diversity, there are few clear cut options that could be considered by the U.S. Congress to encourage such use. The most important suggestions include:

a. Promotion of more high quality research on human-environment interactions in the developing countries. Such research should include the following priority areas:

- o Formulation and testing of more comprehensive conceptual frameworks relating socio-economic considerations to loss of diversity.
- o Detailed case studies of successful and unsuccessful efforts to enlist public participation in the design and implementation of conservation projects.
- o Systematic social and economic cost-benefit analyses of efforts to maintain biological diversity.

An effective mechanism for promotion of such research would be the establishment of special fellowship programs in each of the major world regions (Asia, Africa, Latin America) where USAID is active. Designed to encourage developing country scientists to do research on questions relating to maintenance of biological diversity, these regional programs might be modelled on the highly successful Southeast Asia Population Research Awards Program (SEAPRAP) which was formerly supported by the International Development Research Centre (IDRC) and the Ford Foundation. An annual budget of $300,000 to 500,000 per region for a minimum period of five years could produce a significant increase in both the quantity and quality of research on natural resources management. The Agricultural Development Council (A/D/C), the Ford Foundation, and IDRC recently explored establishment of such a program in Southeast Asia (Romm 1983).

b. Encouraging social scientists to engage in research relating to maintenance of biological diversity by:

- o Establishing programs to train developing country social scientists to do research relating to environmental problems. Such training could be incorporated into the research fellowship program proposed in the preceding section

- o Developing efficient, low cost technologies to make U.S. socio-economic data bases accessible to scientists working in developing countries
- o Encouraging developing country governments to allow social scientists the necessary freedom to carryout their investigations and to publish their results. Special attention needs to be given to the problem of ensuring access for U.S. scientists to field sites in developing countries.

c. Ensure that U.S. Government agencies responsible for projects to maintain biological diversity in developing countries give appropriate consideration to the socio-economic aspects of proposed projects by:

- o Attaching professional social scientists, having area expertise on the country to which they are assigned, to USAID missions and other U.S. field agencies.
- o Requiring that socio-economic assessments be made of all proposed projects to maintain biological diversity before approval of funding is granted
- o Establishing institutional mechanisms for monitoring socio-economic aspects of projects during their implementation phase.

Some years ago USAID experimented with assignment of social scientists, primarily anthropologists, to its country missions to serve as "social analysts." Although several of these individuals were recognized as making valuable contributions to the work of the missions, this inititive appears to have been downgraded if not entirely discontinued. Expression of renewed interest by the U.S. Congress may be required in order to revive it.

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REFERENCES

Abregana, B. C., "Human Disturbances in a Tropical Rainforest: Nature, Views and Approaches," *Impact of Development on Human Activity Systems in Southeast Asia*, Soemarwoto, O. and Rambo, A. T. (eds.), Bandung, Indonesia: Institute of Ecology, in press, pp. 46-64.

Aiken, S. R. and Leigh, C. H., "On the Declining Fauna of Peninsular Malaysia in the Post-Colonial Period, *Ambio* 14(1):15-22, 1985.

Alcala, A., "Research and Development Institute," Silliman University, personal communication, 1980.

Barker, T. C., *Shifting Cultivation among the Ikalahans*, College, Laguna: University of the Philippines at Los Baños Program on Environmental Science and Management Working Paper Series 1, 1984, 32 pp.

Bially, J., *Energy Flows in Subsistence Agriculture: A Study of a Dry Zone Village in Sri Lanka*, (unpublished Ph. D. dissertation), Edinburgh: University of Edinburgh, 1982, 618 pp.

Brett, J. P., "Stonewalls and Waterfalls: Irrigation and Ritual Regulation in the Central Cordillera, Northern Philippines," *Cultural Values and Tropical Ecology in Southeast Asia*, Hutterer, K. L., Rambo, A. T. and Lovelace, G. W. (eds.), Ann Arbor: University of Michigan Center for South and Southeast Asian Studies, in press.

Castro, C. P. (ed.), *Uplands and the Uplanders: In Search for New Perspectives*, Quezon City, Philippines: BFD Upland Development Program, 1984, 314 pp.

Chambers, R., *Rural Development: Putting the Last First*, London: Longman, 1983, 246 pp.

___________, "Rural Development Tourism: Poverty Unperceived," Paper presented at a Conference on Rapid Rural Appraisal, University of Sussex Institute of Development Studies, Brighton, 4-7 December 1979, 14 pp.

Christanty, L. and Priyono, "Measurement of Photosynthesis in Home-Garden Plants with Special Reference to the Perception of People on the Shade and Sun Plants," Paper presented at the Vth International Symposium of Tropical Ecology, Kuala Lumpur, April 16-21, 1979.

Colinvaux, P. A., *Introduction to Ecology*, New York: John Wiley, 1973, 621 pp.

Conklin, H. C., *The Relation of Hanunoo Culture to the Plant World*, (unpublished Ph.D. dissertation), New Haven: Yale University, 1955.

Dahlan, A., Jamieson, N. L., Chu, G., Rambo, A. T., and Vollan, C., *An Interim Report on the Pilot Study in Support of Environmental Communication in Lebak, West Java*, Indonesian State Ministry for Population and the Environment and the East-West Center, unpublished draft report, March 1985.

Dove, M. R., "The Myth of the 'Communal' Longhouse in Rural Development: The Kantu' of West Kalimantan, *Too Rapid Rural Development*, MacAndrews, C. and Chia, L. S., (eds.), Athens, Ohio: Ohio University Press, 1982, pp. 14-78.

__________, "Pendahuluan" (Introduction), *Peranan Kebudayaan Tradisional Indonesia dalam Modernisasi* (The Role of Tradional Indonesian Culture in Modernization), Dove, M. R. (ed.), Jakarta: Yayasan Obor Indonesia, in press.

__________, "Theories of Swidden Agriculture, and the Political Economy of Ignorance," *Agroforestry Systems* 1 (1):85-99, 1983.

Dunn, F. L., *Rain-Forest Collectors and Traders: A Study of Resource Utilization in Modern and Ancient Malaya*, Kuala Lumpur: Malaysian Branch of the Royal Asiatic Society, Monograph No. 5, 1975, 151 pp.

Fowler, C. S., "Ethnoecology," *Ecological Anthropology*, Hardesty, D. L. (ed.), New York: John Wiley, 1977, pp. 215-243.

Grandstaff, T. B. and Grandstaff, S. W., Khon Kaen University-Ford Foundation Project, *Report on Rapid Rural Appraisal Activities*, unpublished report, February 1985.

Grossman, L. S., "Collecting Time-Use Data in Third-World Countries," *Professional Geographer* 36(4):444-454, 1984.

Hallam, S., *Fire and Hearth: A Study of Aboriginal Usage and European Usurpation in South-western Australia*, Canberra: Australian Institute of Aboriginal Studies, 1975.

Hardin, G., "The Tragedy of the Commons," *Science* 162:1243-1248, 1968.

Jamieson, N. L., "Multiple Perceptions of Environmental Issues in Rural Southeast Asia: The Implications of Cultural Categories, Beliefs, and Values for Environmental Communication," Honolulu: East-West Environment and Policy Institute, Working Paper, 1984, 26 pp.

Khon Kaen University-Ford Foundation Project, *Trees in Paddy Fields in Northeast Thailand*, unpublished report, 1984.

Nations, J. "Letter to D. Coules on the Hamburger Connection," *World Rainforest Report*, 3:15, 1985.

Nations, J. D. and Komer, D. I., "Rainforests and the Hamburger Society," *Environment* 25(3):10-20, 1983.

Pei, S., "Some Effects of Dai People's Traditional Cultural Beliefs on the Plant Environment of Xishuangbanna, Southwest China," *Cultural Values and Tropical Ecology in Southeast Asia*, Hutterer, K. L., Rambo, A. T. and Lovelace, G. W. (eds.), Ann Arbor: University of Michigan Center for South and Southeast Asian Studies, in press.

Rambo, A. T., "Community Forestry - The Social View," *Community Forestry: Some Aspects*, Bangkok: FAO Regional Office for Asia and the Pacific, 1984a, pp. 39-46.

___________, "Primitive Man's Impact on Genetic Resources of the Malaysian Tropical Rain Forest," *Malaysian Applied Biology* 8(1):59-65, 1979.

___________, *Primitive Polluters: Semang Impact on the Malaysian Tropical Rain Forest Ecosystem*, Ann Arbor: University of Michigan Museum of Anthropology, in press.

___________, "Why Shifting Cultivators Keep Shifting: Understanding Farmer Decision-Making in Traditional Agroforestry Systems," *Community Forestry: Some Aspects*, Bangkok: FAO Regional Office for Asia and the Pacific, 1984b, pp. 74-81.

Rappaport, R. A., *Pigs for the Ancestors: Ritual in the Ecology of a New Guinea People*, New Haven: Yale University Press, 1968, 311 pp.

Reich, C. A., *The Greening of America*, New York: Random House, 1970.

Rerkasem, B. and Rerkasem, K., "The Agroecological Niche and Farmer Selection of Rice Varieties in the Chiang Mai Valley, Thailand," *An Introduction to Human Ecology Research on Agricultural Systems in Southeast Asia*, Rambo, A. T. and Sajise, P. E. (eds.), College, Laguna, Philippines: University of the Philippines at Los Baños, 1984, pp. 303-311.

Richards, P., "Farming Systems and Agrarian Change in West Africa," *Progress in Human Geography* 7(1):1-39, 1983.

Romm, J., "A Research Agenda for Social Forestry," *International Tree Crops Journal* 2(1):25-60, 1982.

________, "Managing Natural Resources for Sustainable Growth in Rural Income and Equity," An unpublished report to the Agricultural Development Council, August, 1983.

Runge, C. F., "Common Property and Collective Action in Economic Development," Unpublished paper prepared for the Board on Science and Technology for International Development, Office of International Affairs, National Research Council, November, 1983.

Smil, V., *The Bad Earth: Environmental Degradation in China*, Armonk, New York: M. E. Sharpe, 1984, 247 pp.

Soemarwoto, O. and Soemarwoto, I., "The Javanese Rural Ecosystem," An Introduction to Human Ecology Research on Agricultural Systems in Southeast Asia, Rambo, A. T. and Sajise, P. E. (eds.), College, Laguna, Philippines: University of the Philippines at Los Baños, 1984, pp. 254-287.

Stewart, O. C., "Fire as the First Great Force Employed by Man," Man's Role in Changing the Face of the Earth, Thomas, W. L. (ed.), Chicago: University of Chicago Press, 1956, pp. 115-133.

Tisdell, C. A., "Conserving Living Resources in Third World Countries: Economic and Social Issues," International Journal of Environmental Studies 22:11-24, 1983.

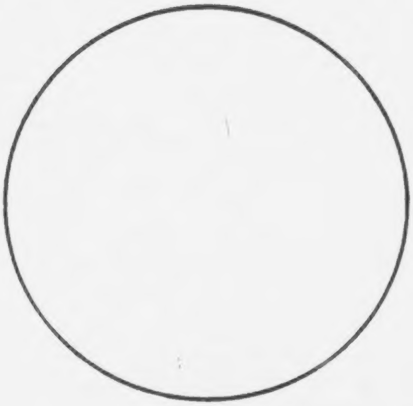
Tuan, Y., "Discrepencies Between Environmental Attitude and Behavior: Examples from Europe and China," Canadian Geographer 12(3):176-191, 1968.

White, L., "The Historical Roots of Our Ecologic Crisis," Science 155:1203-1207, 1967.

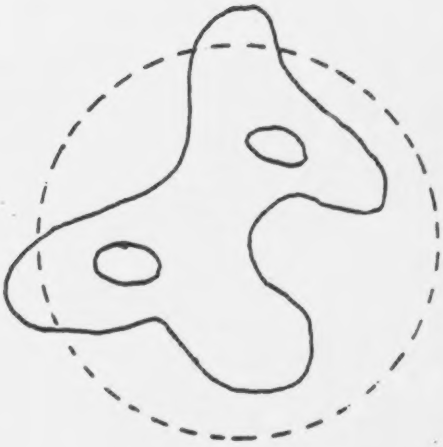
World Resources Institute, Biological Diversity Working Group, Recommendations for a United States Strategy to Conserve Biological Diversity in Developing Countries, unpublished draft report, October, 1984.

Zainuddin, A. R., The Temuan Ecosystem, (unpublished graduation exercise), Kuala Lumpur: University of Malaya Department of Anthropology and Sociology, 1977, 158 pp.

FIGURE 1: FOLK AND SCIENTIFIC ECOLOGICAL KNOWLEDGE



1a. A Total Ecosystem



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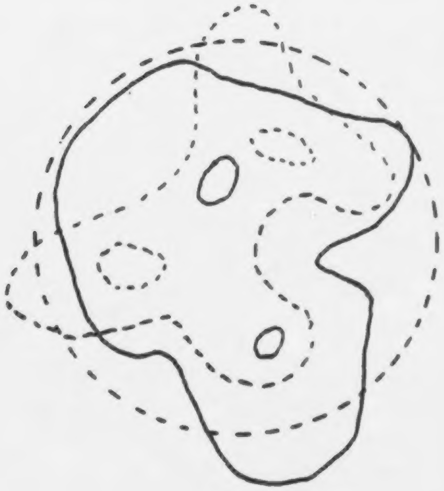

1c. Scientific Ecological Knowledge

Contract Paper No. 8

Conservation of Biological Diversity by In-Situ and Ex-Situ Methods

Gene Namkoong
North Carolina State University

December 1985

Office of Technology Assessment
U.S. Congress

This contract paper was prepared for the assessment of "Technologies to Maintain Biological Diversity." The views expressed are those of the author(s) and not necessarily those of OTA.

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Congress of the United States
Office of Technology Assessment
"Technologies to Maintain Biological Diversity"

CONSERVATION OF BIOLOGICAL DIVERSITY BY *IN-SITU* AND *EX SITU* METHODS

Gene Namkoong

Department of Genetics
North Carolina State University
Raleigh, North Carolina
December, 1985

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Abstract

The primary objective of conserving biological diversity is to ensure the health of the resource for present and future benefits and for the environmental and scientific services the biota renders. However, species differ in their location, amenability to conservation techniques, and relative commercial value. Hence , differend kinds of *in-situ* and *ex-situ* germ plasm management techniques are appropriate depending on the conservation objective as well as on the nature of the biological problem.

For commercial species, breeding theories are described which indicate the flow of genes, populations, and information which originates from unimporved populations, through testing and enhancement, to advanced generation breeding. Most improvement activities do not require *in-situ* techniques and are often directed toward *ex-situ* adaptation. Hence, *ex-situ* techniques are most commonly used but *in-situ* populations often serve as supplements or as substitutes when necessary. For potentially commercial species, the flow of development starts with sampling *in-situ* populations based on ecogeographic surveys, to collection and evaluation and finally into improvement programs. For non-commercial species diversity is primarily conserved in *in-situ* reserves of multiple units of various design with *ex-situ* techniques used in exigencies. Species may simultaneously exist in more than one category and species do flow from one category to another. Since the various categories also serve different but mutually dependent functions for humans, the biota and its management is best viewed integrally. Thus while there exist tendencies for *ex-situ* techniques to be associated with commercial breeding, and *in-situ* with conservation reserves, they should merely be viewed as complementary techniques.

INTRODUCTION

The effectiveness of in-situ and ex-situ techniques for conserving biological diversity depends on three things: 1) the distribution of the diversity to be conserved, 2) the amenability of the species to the different techniques, and 3) the objectives of the conservation programs. Biological diversity not only lies in different geographic locations and in temporally variable patterns, but also exists at different levels of biotic organization. It may be discussed in terms of variation at the molecular, sub-genic level of organization, at the genic and individual organismic level, and at the population, species, and ecosystem levels, and therefore can be measured in many ways. In addition to variations in the status of diversity, species differ in their adaptability to techniques of tissue culture, seed storage, or sustainability in other than natural conditions. Thus, while ex-situ seed storage might be desirable for some purposes, it may not be possible for some species such as those with recalcitrant seed. Furthermore, even if such techniques are feasible, they may not be appropriate for programs requiring some degree of natural selection and evolution instead of breeding for advanced commercial crop varieties. Obviously, no one technique can be successful for all purposes and a global strategy requires a choice of management tactics and techniques for each part of the biota. Hence, the effectiveness of the specific techniques for a wheat breeder can be very different from the point of view of a tropical forest ecologist and can also be different for present vs. future generations.

Never the less, for a global strategy of conserving diversity, the status of species needs, the biological appropriateness of technologies, and the uses of populations, can be arrayed and the efficacy of the techniques objectively judged. In this paper, six types of germ plasm management programs are considered: advanced breeding, enhancement, collection and evaluation, ecogeographic survey, targeted sampling, and biological reserves. This is an arbitrary subdivision of a continuum of activities used in gene conservation and breeding, but is useful for condensing discussion around real operational differences. In each of these management categories, various in-situ and ex-situ techniques are considered. Included under in-situ are: maintaining strict reserves with natural survival and reproduction; population sampling, surveying and evaluation in natural conditions; collection, enhancement, and possibly even breeding by such management techniques as thinning, breeding, transfer, etc.; and constructed populations established within the species natural range. Included under ex-situ are: seed, pollen, and tissue storage; population trials outside of the species natural range including botanic and zoological gardens; population management or naturalization away from the population's original site, including domesticated varieties. Obviously, this too represents an arbitrary subdivision of a continuum of activities which is never the less useful for understanding the array of activities which are involved in global germ plasm management. While it is not surprising that the utlity of the various techniques and management strategies are viewed quite differently for specific programs, those differences should not obscure the underlying unity possible for a global strategy to conserve multiple levels of diversity with multiple techniques.

To evaluate the efficacy of the various in-situ and ex-situ techniques it is necessary to first briefly review the nature of the biological diversity we seek to conserve to establish an evaluative perspective. For some preservation objectives, the non-extinction of species is sufficient, but for some breeding objectives genic level diversity is necessary. Since it is a practical impossiblity to conserve all genes of all species and not necessary for all purposes in any one species, we must define the levels of biological organization and the conditions of their conservation which are necessary or sufficient for our objectives.

Recent studies on the molecular structure of genes and on levels of allelic variation within and among loci, reveal little doubt that a wealth of genetic variation exists within most plant and animal species. Furthermore, studies on the mating and selection of individuals and populations within species are revealing a more complicated view of intra-species structures and the possible significance of evolution at the population level. Evolution at this level may also be driving and be driven by other species such as competitors, predators, diseases, or others, and hence may affect the structure of multiple species ecosystems. However, while variations of lower level effects are necessary conditions to generate higher level variations, they are not sufficient conditions and hence considerable debate exists on the relationship between population level variation and ecosystem variation. Never the less, the fact that species generally contain diverse structures is not debated, and the potential utility of this variation to humans is also beyond serious doubt.

At issue is whether the variation within species is uniformly distributed throughout the species range or if it is grouped. If of the former type, then any one sufficiently large sample would contain all variations, but if of the latter type, then multiple population samples would be required. At the one extreme, a species may exist as a collection of disparate populations with some past but little present intermating and with widely different adaptations to different local selective environments. Either one or both sexes may have restricted migrations and may also be subject to both survival and reproductive selection effects within and between populations. In such species, the divergence of its constituent populations may be so great as to render the species concept almost meaningless as each local population may be generating unique genotypic arrays. In these cases, conserving diversity requires conserving each population.

At the other extreme, a distinct species may exist in a unitary habitat with complete inter-mating opportunities for all individuals and with no genetic substructures. In such species, population size and selection effects are not complicated by differences among populations and even if variation among demographic groups and at different levels of genic organization make our understanding of species dynamics more difficult, the species can be treated as a single evolutionary unit. Thus, the pattern of diversity of the population level of biotic organization determines the adequacy of single vs. multiple sampling strategies. Population level conservation is sufficient for genic and species conservation if the species is very simply structured, and is necessary if very diversely structured.

Obviously, most species of plants and animals are at neither extreme, but rather have some restrictions in effective migration in at least one sex, exist over an array of selectively different environments which share partially common boundaries with mating-migration boundaries, and experience temporal variations in both (Roughgarden, 1979). While some species seem to develop highly specialized and integrated features of their adaptive behavior with their mating and gene action systems, other species seem to be able to change their mating-migratory behavior almost simultaneously with their changing environmental circumstances (Hedrick, 1983). In addition to directed forces of evolution, stochastic variations within and between populations can further diversify populations. Thus, from the evidence of the relatively few cases in which genetic studies of species include anything but the most simplistic ecological effects, the formation and significance of patterns of genetic variation within species is neither uniform nor easily estimated. While it may at times be a practical necessity to conserve species with only one population sample, in general, some multiplicity of samples will be desirable. If the species is known to have a center of diversity or a concentration with border populations, a reasonable sampling strategy would focus on the main body, with extra samples spaced among the outliers. However, if the species variation is known to be uniformly dispersed, or if we are ignorant and must assume a uniform probability of sampling useful genes, then there is no central population and all samples must be uniformly dispersed.

Another element of the biological nature of species which affects the relative adequacy of ex-situ conservation is whether the particular in-situ environment is an important feature in the survival or utility of the species' populations. In particular, when the environment is considered to include other species of the biome, the potential for greater evolutionary complexity exists and for the significance of subtle genetic variations to be obscured from our understanding (Levin and Udovic, 1977; Namkooong and Selgrade, 1986). Multiple, interspecies relations can be important in defining critical elements of both survival as well as reproductive success. However, even considering only pairwise interactions of species which contain genetic variations within each, the existence of single, globally stable equilibria is clearly not the only feasible way that strong interactions can maintain two species co-existence (Selgrade and Namkoong, 1985). Multiple equilibrium points along with stable periodic solutions may exist, and hence populations may change from one configuration of population densities and gene frequencies to another, or may cycle among such states. Since such behavior can be driven by a constant set of selection coefficients, the effect of interspecies relations can be different from place to place and time to time. This makes the statistical analysis of evolution very difficult, but more importantly it implies that different population samples can be driven to different states of genetic and species composition by the same selective forces. Thus, even without the existence of other environmental differences among populations, natural evolutionary processes can produce a diversity of multiple populations all of which may be significant in the evolution of each constitutent species and hence would be desirable to sample. More over, this would imply the necessity of not only multiply sampling the species, but may also imply the necessity of in-situ conservation for species survival and evolution.

Thus, the biological nature of diversity may determine the desirability of different in-situ and ex-situ techniques, but the risks and costs of those techniques may constrain the final program choice. Some species may be physiologically incapable of maintaining seed or pollen viability, growth in tissue culture, or even under stand management techniques. For some other species, such techniques may be possible but costly, or may require more knowledge than we have to ensure security of collections. On the other hand, the security of in-situ conservation areas may be in political or economic jeopardy or may require locations so remote from use, that they are practically inaccessible. When physiologically possible, ex-situ techniques may be the only way to conserve genes and species even if it isolates samples from beneficial evolution. Thus, the biological and geographical amenability of species to conservation techniques can determine their practical applicability.

Finally, the effectiveness of techniques will substantially depend on the objectives of the conservation program. For the immediate use of commercial breeders, long term evolutionary potential may be relatively unimportant and any sample of immediately useful genotypes is sufficient. However, the existence of diverse evolutionary paths may be important for the multiple environmental services which the biota performs and from which humans benefit. These in-situ services include cryptic effects on our physical environment, such as on water and air regimes, secondary biological boilogical support of agricultural systems such as on pest and pathogen control and by nutrient recycling and waste absorption. Other services, such as the direct effects of supplying new biological products for medicine, food species, or the provision of genes which might be transferrable into crop development systems can still be provided by in-situ programs. However, the plant or animal breeder who is trying to introduce modifications to well established varieties is primarily interested in particular genes or traits and not on general trait clusters or adaptabilities. For these purposes, saving genes with efficiency, security and completeness are the main objectives for immediate use of biological diversity and ex-situ, if possible, conserves genes more conveniently. For cases where more substantial changes are either necessary or desirable, then whole population breeding for substitution of other varieties or for hybridization may be necessary. In these cases, alternate populations may be developed for adaptation to particular environments or pathogens, or for economic requirements, and these may be used simultaneously or in tandem in multiple varietal combinations. They may be targeted for particular sets of environments (Comstock, 1977) or simply designed for adaptation to an array of environments along some measurable environmental gradient. For these cases in particular, the adaptations which species develop for different environmental conditions in-situ may well be useful to further enhance by breeding for diverse objectives. There is, therefore, a wide array of genetic management programs appropriate for the different objectives of conservation and for the different stages of development required for use. For some crops in commercial agriculture in the Western, industrialized world, there is a long sequence of developmental stages for use of germ plasm which focuses on genes, lines, or varieties, and involves population development programs which would be inappropriate for other crops or other uses. Thus, species development programs may be lacking in any of its several populations and the appropriate techniques needed for adequate conservation will depend as much on program needs as on the biological status of the species.

In the following, the biological status and conservation objectives are discussed as factors determining program choice. For convenience, the discussion is organized according to economic utility. The discussion of techniques used for conservation of biological diversity is begun with the species of present commercial interest, then the species of secondary or potential commercial value are discussed, and finally, those species of no forseeable direct commercial value are discussed. Consideration is then given to the integration of programs for all types of species.

Commercial Species

For species which have entered some commerce, the actual variety used is but the last population in a sequence of increasingly selected populations. To achieve a successful commercial culmination, activities can be considered to start with surveys of extant variability. An ecogeographic survey may be an informal observation of the origin of species variants, more elaborate in-situ studies, or may be coupled with ex-situ tests relating performance to variations in the sites of origin. Such field surveys are proposed for wheat in Turkey and the near East. This is followed by selective breeding to further enhance the value or adaptability of the population for existing standards in the areas of use. Such enhancement populations may involve several generations of selection, crossing, and backcrossing, for example oats and sorghum breeding with wild relatives takes four to six generations of inter-crossing, before they enter advanced breeding and eventual commercial release.

Tracing this sequence backward in time, the breeders' base populations or foundation stock are defined as those populations from which ordinary selective breeding can develop varieties of direct value to commerce. These are the populations found in agricultural experiment stations or plant seed companies with which some history of work or familiarity exists. They may be a diverse collection of semi-independent ancestry selected for diverse economic or ecological adaptability, or may be a single land race or traditional variety of proven value. Depending upon how narrowly based these populations are with respect to economic or ecological demands, or how little genetic variation may exist in the breeding populations, new populations may often be needed. Ordinarily, populations found in the wild or in farming or forest conditions which are different from the environments of commercial applications, require some enhancement before they can be used in advanced breeding programs. This enhancement may take the form of selective breeding within these populations to eliminate deleterious traits or to increase value and adaptability to commercial production. Independent populations are possible to develop as substitutes or competitor varieties. Alternatively, a population may be most easily enhanced by crossing into established varieties and selecting among later generations of segregants (Frey, 1984). Depending on how these enhancement activities are carried out, genetic diversity within varieties may be increased or diminished, but as long as populations are kept separate, useful diversity between varieties may well be increased.

To ensure the continued availability of useful foundation populations, Kannenberg (1984) suggests that hierarchies of populations be established. In these, one or two base levels of partially enhanced populations feed genes, individuals, or populations into advanced breeding generations which are more narrowly selected. In the same volume, Namkoong (1984) suggests that multiple populations which are simultaneosuly developed better serve the needs of breeders of species which have longer breeding cycles or for which predictability of future needs is poor. In either case, some enhancement activities are assumed to be necessary to bring wild or differently adapted populations into commercial use. For species in which characterized races are known and require maintenance which excludes selective or other evolutionary change, storage methodologies are required. Seed, pollen, tissue storage or living clonal collections represent such evolutionary fixations but even they are subject to accumulations of mutants and viruses. For populations which must undergo sexual reproduction, inbred lines are more genetically constant but even for outcrossing species, varietal purity requires strictly intra-varietal mating.

The gap between populations used in advanced breeding for commercial varieties and wild relatives or varieties used in more primitive agriculture is often wide. Enhancement activities often start with at least informal surveys of ecogeographic variation, from which to select promising populations for collection and evaluation. When the areas for which the breeding is intended overlap with the areas of origin, such evaluations are often in-situ, but when uses over wider ranges are intended, ex-situ testing is desirable. Even then, however, if reproduction is difficult, expensive, or risky, in-situ collections may be the only reliable means of continuous safe storage of the original germ plasm. Ground nuts, oil palm, banana, rubber, coffee, and cocoa fall into this category as do most of the wild relatives of our fruit trees and forage plants.

For less intensively managed species or those with telescoped development, there is a blurring of distinction between the collection and evaluation populations and those in which selection enhances the populations sufficiently for direct use. This often occurs in forestry where seed source testing may lead directly into use of selected trees for commercial seed production. For other species with possibly more highly developed breeding populations, the stages are more distinct and collection may involve only those sources which happened to have been used in some locality without any purposefully directed sampling of evolutionary diversity. Extensive ex-situ collections are maintained for such imporant grains as rice, wheat, and maize which support many local testing, enhancement and breeding programs. Most such collections as at the IARC's and at the National Seed Laboratory, are intended to completely sample the present distribution of alleles and pouplations and pay little heed to geographic or environmental patterns of adaptation. However, in face of the loss of wild relatives and local varieties of these species, broader population samples and ecogeographic in-situ studies are being encouraged by such agencies as FAO. Since most of testing and enhancement activities occur near to the areas of ultimate use, quite distant from areas of origin, the materials are necessarily in an ex-situ situation. In these cases, seed or tissue storage may function as secure sources of material for testing and use and if collections are complete, they serve as a static repository of the species evolutionary history, genetically fixed at the time of sampling. As long as such collections are secure either in individual repositories or in several duplicate sets, and the species evolves only within well-established agricultural environments, there is little need for other repositories. A danger exists, however, that seed or tissue collections, and repositories, or living conservation collections of plants or animals for these purposes may destroy existing diversity by homogenizing all populations. To preserve the sampled diversity separate source populations must be kept distinct, or multiple, in-situ storage areas must be maintained.

We might therefore characterize the management techniques used for commercially important species as ranging from advanced breeding with its supporting enhancement populations, to targeted collection and evaluation based on ecogeographic surveys (see Figure 1). With wheat, the IBPGR is proposing support for the ecogeographic surveys, while several national agencies and IARC's are supporting collection and enhancement programs, and other public and private agencies are in advanced breeding. These are often largely ex-situ programs. However, in-situ is used for initial surveys, and when areas of use and origin overlap and when the ex-situ techniques of seed or tissue collection and storage are either unavailable or insecure such as with species with recalcitrant seed, or where ex-situ living collections are not maintainable. In the future, if more species enter commerce, then greater use of in-situ or naturalized ex-situ populations may be seen.

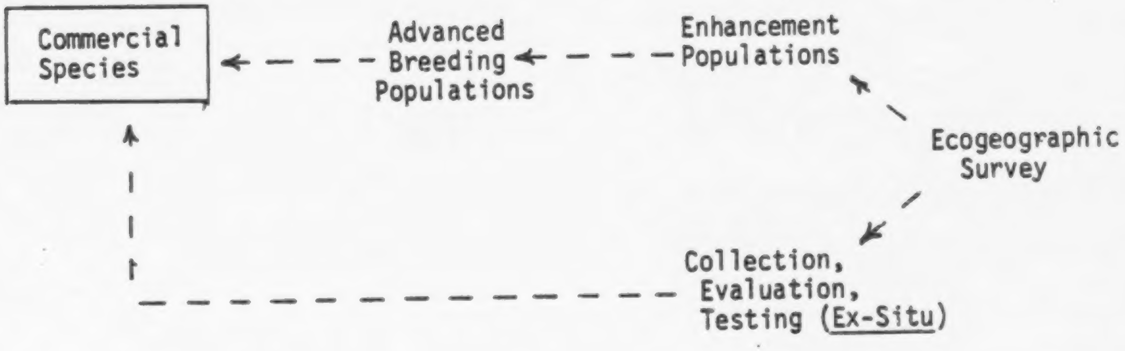
Commercial Species
Advanced Breeding Populations
Enhancement Populations
Ecogeographic Survey
Collection, Evaluation, Testing (Ex-Situ)

Figure 1.

Commercial Species Composed of Multiple Advanced Breeding Populations. Populations may be a hierarchy of enhanced populations or the advanced breeding populations may be augmented by developed varieties.

Potentially Commercial Varieties or Species

The development and use of the primary commercial species are usually based on substantive biological and economic reasons and immediate pay-offs are to be expected from investment in these. Never the less, as pests and pathogens change, as climates, soils, and arable land change, and as technologic and economic requirements change, the list of primary varieties and species will also change. The need to develop alternatives originates not only from shifts in adaptational requirements but also from the need to generate useful genetic variation in crop species. Populations are therefore needed to serve as sources for enhanced breeding populations and, either directly or ultimately, for advanced generation breeding. Even such primary grain crops as wheat are now recognized as being deficient in the supply of support varieties and require more extensive survey and sampling of non-commercial varieties and wild relatives. In addition, there are many species of local or limited use which are important supplements for diet or medicine, and many others which can be developed to higher levels of utility. Consideration should therefore be given to a few hundred species instead of a few tens of species of primary commercial use.

For these species, the available management techniques are usually less capital intensive since returns on capital investment are longer in coming and less certain of achievement. Never the less, trials of secondary or non-commercial varieties and species often have been established to either replace others entirely, or to serve as a source of genes for back-crossing, hybridization, or possibly for gene-transfer into established varieties. The uses of in-situ and ex-situ techniques are different for populations which serve these purposes than for advanced commercial varieties, and differ among the various applicable management techniques. These programs usually have two principal objectives:

1) Sampling the distribution of genetic variations and understanding present patterns and past causes of that distribution, and
2) Analyzing and discriminating useful differences among genes, individuals, or populations.

The first objective involves targeted sampling and ecogeographic surveys and is aimed at understanding the distribution of genetic variation for biological insight as well as enabling breeders to sample populations for useful traits or genes more efficiently. As such, it involves studies on the structure of species, the ways in which allelic or gametic frequencies may be heterogeneously distributed, and the extent to which such patterns may have been related to species evolution and may be useful for its future survival or commercial use. One of the problems faced by investigators of population structure is that they can only study existing patterns of variation or at most, only a few generations, and these have usually already been altered by destabilizing human and other interventions. If as earlier suggested, multiple equilibrium states may exist within a complicated global dynamic, then the samples available today do not represent a single stable equilibrium. Thus, the distribution of alleles in their present state does not necessarily represent any natural stable equilibrium or optimal condition. It is more important to track population changes and to allow the species to evolve within an array of environments primarily _in-situ_ but also possibly in a combination of _in-situ_ and _ex-situ_ conditions.

The second objective is directed toward finding useful variations regardless of mode of origin and involves ecogeographic surveys with collection and preliminary evaluation _in-situ_. To test wider adaptability, the design and analysis of _ex-situ_ tests are well known and, given a sample of populations, the patterns of genetic variation in test environments may be discernable. Such _ex-situ_ ecogeographic studies can direct population re-sampling if the traits desired are not sufficiently well developed in the initial sample, or it may be decided that sufficient gain can be achieved by breeding within previously sampled populations. For some Central American pine species, ex-situ stands are the only physically secure means to maintain valuable population sources. Once endangered sources of germ plasm are secured, geneticists trust that testing and enhancement programs can then be carried out. Thus, the source materials for testing and development must be some ex-situ or in-situ sample of the available gene pool. As a minimum, such a sample must be large enough to have a reasonable chance of saving the useful genes. Even with the best sampling efforts, however, this minimum may miss many alleles if they are rare in the places and time of the sample. Thus, to minimize the probabilities of losing alleles, sampling must either be sufficiently redundant or directed to a pattern of areas covering populations most likely to yield allelic variants. Hence, knowing the population genetic structure of these species helps determine the sampling structure. For species of only potential commercial interest, the sampling will largely be in-situ.

To reflect the structural diversity which may exist in populations, targeted samples are needed from different areas, populations, and individuals. It may also be necessary to sample communities in different stages of development, with respect to their own population dynamics or to other non-constant variables of the environment and mating patterns. However, the only recourse we often have is to sample and maintain sufficiently large populations so that even those alleles which occur at low frequency would have high probability of being saved. Guidelines can be provided for population sizes and distribution, but these must be surrounded by caveats with respect to risks to population integrity and reproduction (see Namkoong , 1985).

The more information available on the centers of diversity or dispersal patterns, the more efficiently can the sampling be designed. Not only should central populations be sampled, but also populations from extreme sites and isolated locations may contain adaptational features in high frequency. For sub-climax species, a variety of different site occupancy ages might also be useful to sample. For species which evolve with competitors, mutualists, or pests and pathogens, a multiplicity of population samples increases the chances of finding populations with higher frequencies of useful but rare alleles. For disease resistance alleles, it may often be more useful to sample alleles which have coevolved with pathogens, since these may be most useful in breeding for stable host-pathogen systems. For rust diseases on grain species, Leonard (1984) suggests that resistance alleles co-evolved in-situ, are more likely to permit ex-situ stabilities to evolve. There may also exist special indicator variables, physical or biotic, which imply the existence of a substantial frequency of generally rare alleles, and as ecogeographic studies progress, these too may be used to target sampling of in-situ populations.

Once the sampling is determined, in-situ conservation for collection and evaluation is:

1) necessary when ex-situ cannot succeed for biological or technical reasons, such as wild fruit and nut species,
2) useful when the local environment provides the support factors or desired evolutionary pressure for that species and when population sizes cannot be maintained in ex-situ collections, such as the forage species, and
3) desirable when we are ignorant of the species' needs.

Ex-situ is needed when the natural locations are insecure, or are distant from where the species is needed for development, testing, and enhancement; it is most useful when the natural populations cannot be secured and when ex-situ conservation is cheaper and is desirable as a backup for in-situ population samples.

Various species require vastly different areas for their conservation since they are different in individual organism size and dispersal patterns. Different mixtures of in-situ and ex-situ populations will be needed. It may also sometimes occur that the natural dispersal of a species may be so wide in certain areas that the conservation of a local population may require more area than can be accommodated. In such cases, transplanting or moving individuals into higher density semi-managed conditions might be considered in order to condense its distribution within approximately normal environments. This may not be possible for some species to endure, and for many species would entail an adaptation to new environmental conditions, but may often be useful as a means of capturing the advantages of both in-situ and ex-situ techniques. This is commonly done with forest trees and is very useful whenever natural stands are in danger of physical destruction.

In order to ensure the existence of appropriately distributed sample populations, species' population sizes and location distributions should be determined and cross-checked with existing reserves and conservation areas. Then, a coordinated plan for supplementary ex- and in-situ conservation areas can be drawn up based on the security of reserved areas for gene conservation purposes.

In Figure 2, the management techniques useful for these varieties and species which have clear potential commercial value are diagrammed along with the management categories for commercial species. Several tropical pine species of potential commercial value are included in targeted samples and ecogeographic surveys of in-situ stands, but collection and evaluation is heavily in ex-situ test plantings. It should be noted that it is not necessary for populations which exist in test or conservation stands to follow all of the protocols of commercial breeding. It may often occur that the process is telescoped and test populations immediately become commercial varieties, especially in species without a long history of commerical breeding development. In the future, if the potential commercial value of more species is recognized from present explorations and molecular genetic technologies, in-situ sampling may become more important while ex-situ testing may be more widely used.

	Advanced Breeding	Enhancement	Collection & Evaluation	Ecogeographic Survey	Targeted Samples
Commercial Species	Advanced breeding/ selection for commerce	Intensive testing & selection	Collect and test ex-situ (in-situ if necessary)	Survey patterns of variation and store ex-situ & in-situ	
Potentially Commercial Species			Collect for diversity, store ex-situ (in-situ if necessary)	Identify patterns Sample for diversity. In-situ and ex-situ storage	In-situ or mixed in- and ex-situ samples

Figure 2.

Management Technique Array for Commercial and Potentially Commercial Species

Non-Commercial Species

Beyond the few hundred species already considered, the vast majority of a few hundred thousand plant species and a few hundred million animal and insect species serve no direct commercial function. However, there are at least three possible functions for these other species which force us to consider their welfare: their potential for direct use, our need to understand natural population processes, and their support of ecosystems which stabilize benefits to humans.

The potential for direct use by varietal substitution of traditional food crops by any new species is not high since past human activity has probably effectively screened the available biota. However, for newly understood or developed products such as medicines or pesticides, where new uses or processes force new criteria of usefulness to exist, or even for food where new processes change the environment for economic production, previously non-commercial species may become important. With the newer possibilities of genetic engineering, almost any species might contribute useful genes or processes. Since our understanding of the evolution of even the commercial species is so tenuous, it is clearly beneficial to at least maintain a sample of the evolutionary system. By learning about the possible behavior of interacting systems, we can then be informed of the possible ways that the human economy can function in a more stable interaction with the biota. The design of future agricultural systems may lead to more stable ecosystems and to the construction of populations with broader adaptabilities to variable environments.

The contribution of non-commercial species to ecosystem functioning and stability cannot be lightly dismissed. While highly complex and interdependent webs of association may often be fragile and easily degenerated with high extinction rates of component species (May, 1973), the existence of fragility does not imply that species or systems should be allowed to die. Rather, for our own benefit, the various functions of non-commercial species should be understood to include the long-term productivity of all other parts of the ecosystem. Thus, even apparently unimportant species may be critical to the functioning of commercial agriculture, and some most certainly are. Our ignorance of which species and which functions have greater or lesser importance only forces us to consider conservation of more species than are minimally necessary.

The management options for these populations are more restricted than for commercial species and stands. Some form of *in-situ* conservation seems necessary as for tropical forests, even though it may be neither the most secure nor the least costly option. Since species values are likely to be associated with community functions, conservation is perhaps most easily assured by area management as in reserves~~,~~ parks, or natural areas. Natural areas are chosen mainly to maximize species level diversity, but this is not necessarily sufficient for intra-species diversity. The requirements of population size and multiple population dispersal remain the same for each constituent species, and since little direct control of each species in any one area can be expected, sample dispersal and redundancy is needed in size of individual areas and in numbers of separate populations. For species with structural diversity it is not enough to conserve one ecosystem sample. For species that respond to known environmental variables, including the coevolution of other species, sampling from the range of those variables is necessary for capturing significant genetic variability.

For many species, however, even such recommendations are futile, since so little is known of the species distribution or even of their existence. For these, targeted sampling in centers of diversity such as the Brazilian Amazon as outlined by Pires (1978) may be the only realistic hope of their conservation. A minority of the hundreds of species per hectare are known and mapped. Obviously, where known centers of diversity exist within a known species, those would be prime targets for sampling. Supplementary sampling from more extreme populations is desirable (Namkoong, 1980). Similarly, the design of natural reserves should not focus exclusively on centers of origin or diversity, but should also include areas of more extreme habitat of the various biotypes to ensure that the genetic diversity of the contained species is well sampled. Thus, in order to conserve the viability of an ecosystem and to ensure the availability of genetic variations, the dynamics of species evolution generally requires multiple area and multiple population sampling.

Whether we consider a species and its associates to be of commercial value or not, we know that genetic and ecological variations are not likely to be in an evolutionarily static state. While some may have impoverished gene pools, and some may contain all genetic variations within single large populations, most must be considered to be in some transient evolutionary state. Whether they have been stable in the recent past or not, human activities have probably at least changed many of their equilibria. For managers of genetic resources, the goal is not to conserve a static state, but to contain a dynamic system, even though our understanding of its dynamics is very meager.

In Figure 3, the necessity of using in-situ reserves is emphasized for the non-commercial species, due to its practicality and the necessity to allow the populations to evolve. This is not to exclude certain ex-situ practices such as introducing populations of key species such as trees or primary feeders to alter or reestablish an ecosystem. Moreover, the mutual evolution of many different kinds of species at different successional stages and trophic levels requires that often conflicting practices be considered. For pioneer and secondary successional plant species and the animals dependent on them, some continued disturbance types, sizes, and frequences are required, while climax communities require less disturbance. Some large mammmals may require continuous cover, while plants at the border of fields and forests may require discontinuous habitats. Because some of these requirements cannot be simultaneously met due to physical or managerial limitations, and for reasons of safety, a multiplicity of sites and management regimes is required. Compartmental management systems can be designed with some compartments kept under strict preservation status, others under frequent disturbance, and other sets with designed juxtapositions of successional stages. Some deliberate intervention will often be necessary to preserve certain processes and species, and targeted sampling of special sites may be needed to supplement any general purpose network. Thus, establishing samples of critical ecosystems is but a necessary first step in the establishment of a network of natural and managed areas. While efficiency demands that natural area reserves contain maximum diversity, they alone are not sufficient for conserving much of the biological diversity.

	Advanced Breeding	Enhanced Population	Collection & Evaluation	Ecogeographic Survey	Targeted Samples	Biological Reserve Network
Commercial Species	Selective Breeding	Testing/ Selection	Testing *Ex-situ* (*In-situ* only if needed)	Survey patterns and store *Ex-situ* and *in-situ*		
Potentially Commercial Species			Collect and store *ex-situ* (*In-situ* if needed)	Identify and sample *In-situ* (*Ex-situ* storage if needed)	*In-situ* samples (*Ex-situ* if needed)	
Non-Commercial Species					*In-situ* samples	*In-situ* General Purpose

Figure 3.

Management Array for All Species

Global Systems

In any global strategy for the conservation of biological diversity for all the values which the multitude of species provides, account must be taken of the mixed objectives for, and the mixed biological status of, the array of species. There is a biological continuum of species, populations, and varieties, which fill various commercial and non-commercial needs, and for which various mangement programs and in-situ and ex-situ techniques are appropriate. There is also a flow of species and varieties among these categories of use and among management techniques. Thus, there can be no simple distinction made among species or management methods which consistently separates the usefulness of in-situ from ex-situ techniques. In fact, they often support one another in the same species programs. For example, in-situ populations lend security to ex-situ collections for breeding, while ex-situ seed storage may provide security for in-situ conservation populations threatened with local extinction. However, even when not supporting each other, different agencies may act on the same species with different objectives and pursue different population support techniques. A global strategy would have to account for the variety of objectives and management techniques available and consider which problems are most urgent to attack.

Obviously, the choice of technique is closely tied to the program objective and biological requirements, and there is a strong tendency for advanced breeding populations of commercial varieties to use ex-situ techniques while reserves for non-commercial species tend to be in-situ in character. Thus, there is also a tendency for commercial interests on present value returns on investment to emphasize ex-situ techniques, while the use of in-situ reserves is mainly directed to long term and uncertain or diffuse values. The integration of species and their management techniques is therefore also arrayable along an axis of time or remoteness from commercial use (Figure 4). While the commercial breeder may wish to extend the utility of his varieties into the future, and the conservationist may wish to increase the immediate pay-offs on investments in biological reserves, they are essentially approaching the biota from opposite poles. Breeders view the biota from the far, upper left of the box in Figure 4 and can rarely see the value of the near, lower right, while preservationists view the biota in just the opposite direction. The continuity to the management of the biota and the existence of different values to be derived by different users, is often missed. Thus, the fact that in-situ and ex-situ techniques often complement each other, especially for potentially commercial species, is not recognized, and in fact not supported by either breeding or conservation interests.

Clearly, it is far more efficient to develop an integrated program for all segments of the biota for the good of present and future generations. Natural areas can as well include disturbed areas and species which may in some form be amenable to mechanized agriculture as well as species with no known use or ecological impact. Population enhancement can as well be used for natural area management as for developing commercial breeding objectives. While it is to be expected that only certain techniques would be used on certain populations by any one interest group, an agency which must satisfy the commercial and non-commercial objectives of conservation must consider the continuum of species uses and gene management programs. The uses of in-situ and ex-situ techniques, either exclusively or in combination for each species and management category can then be selected according to need and efficiency.

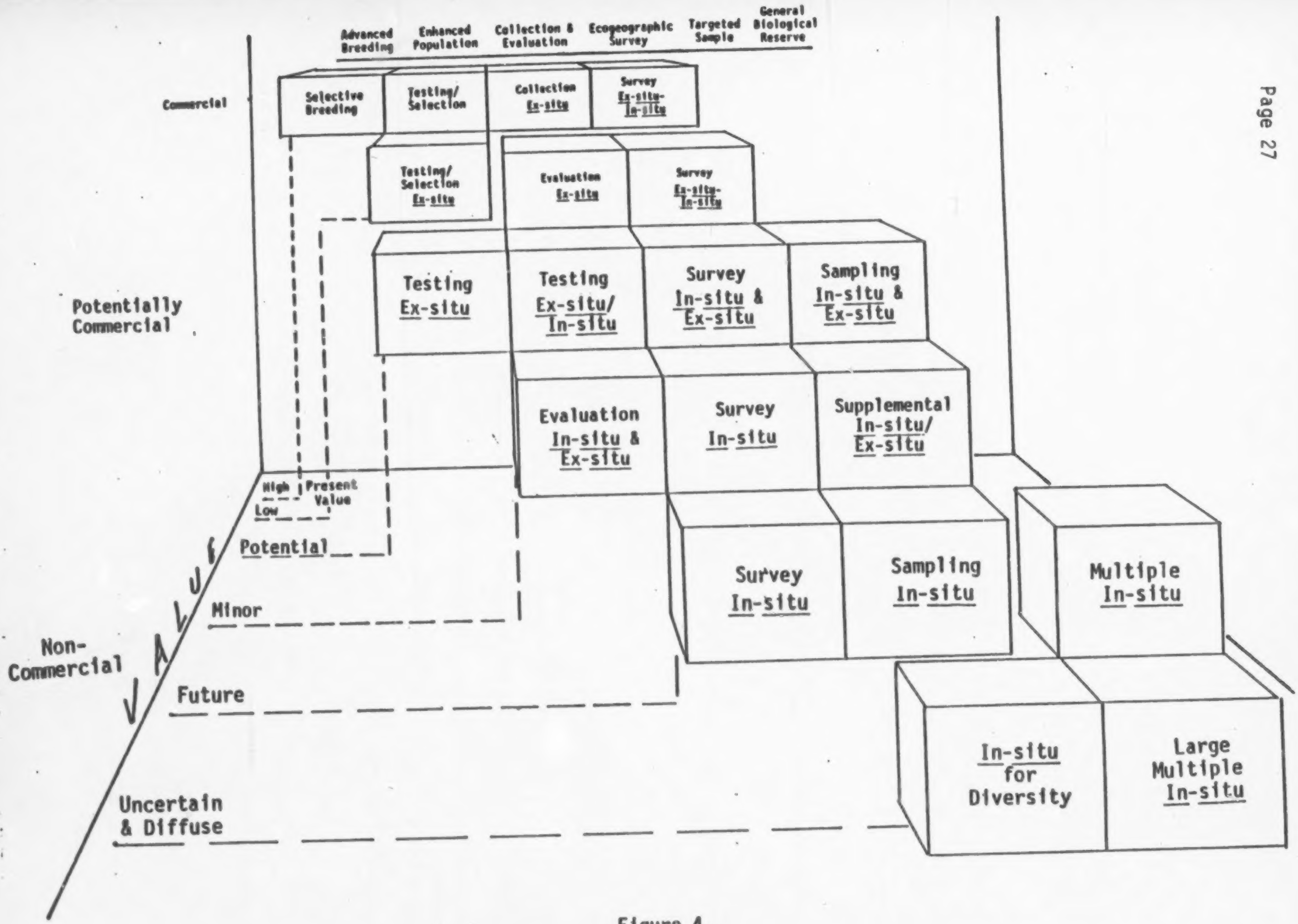
Advanced Breeding
Enhanced Population
Collection & Evaluation
Ecogeographic Survey
Targeted Sample
General Biological Reserve
Commercial
Selective Breeding
Testing/ Selection
Collection Ex-situ
Survey Ex-situ- In-situ
Testing/ Selection Ex-situ
Evaluation Ex-situ
Survey Ex-situ- In-situ
Potentially Commercial
Testing Ex-situ
Testing Ex-situ/ In-situ
Survey In-situ & Ex-situ
Sampling In-situ & Ex-situ
Evaluation In-situ & Ex-situ
Survey In-situ
Supplemental In-situ/ Ex-situ
High
Low
Present Value
Potential
Minor
Non- Commercial
VALUE
Future
Survey In-situ
Sampling In-situ
Multiple In-situ
Uncertain & Diffuse
In-situ for Diversity
Large Multiple In-situ

Figure 4.

Management Techniques Arrayed by Time-Remoteness of Value

List of References

Comstock, R. E., "Quantitative Genetics and the Design of Breeding Programs," *Proceedings of the International Conference in Quantitative Genetics*, Ames, Iowa, Aug. 16-21, 1976, pp. 705-718.

Frey, K. J.; Cox, T. S.; Rodgers, D. M.; and Bramel-Cox, P.; "Increasing Cereal Yields with Genes from Wild and Weedy Species," *Proceedings 15th International Congress of Genetics*, Vol. 4, New Delhi, India, 1984, pp. 51-68.

Hedrick, P. W., "Genetics of Populations," N.Y., Van Nustrand Reinhold Co., 1983, 629 pp.

Kannenberg, L. W., "Utilization of Genetic Diversity in Crop Breeding," *Plant Gene Resources: A Conservation Imperative*, Yeatman, C. W.; Kafton, D.; and Wilkes, G.; (eds.), AAAS Selected Symposium 87, Boulder, CO, Westview Press, 1984, pp. 93-110.

Leonard, K. J., "Population Genetics of Gene-for-Gene Interactions between Pathogen Virulence," *Proceedings 15th International Congress of Genetics*, Vol. 4, New Delhi, India, 1984, pp. 131-148.

Levin, S. A.; and Udovic, J. D.; "A Mathematical Model of Coevolving Populations," *American Naturalist* III: 657-675, 1977.

May, R. M., *"Stability and Complexity in Model Ecosystems,"* Monographs in Population Biology No. 6, Princeton, NJ, Princeton University Press, 1973.

Namkoong, G., "Genetic Considerations in Management of Rare and Local Tree Species," *Proceedings Conference on Dendrology in the Eastern Deciduous Forest Biome*, Blacksburg, VA, 1980, pp. 59-66.

Namkoong, G., "Strategies for Gene Conservation in Forest Tree Breeding," *Plant Gene Resources; A Conservation Imperative*, Yeatman, C. W.; Kafton, D.; and Wilkes, G.; (eds.). AAAS Selected Symposium 87, Boulder, CO, Westview Press, 1984, pp. 79-92.

Namkoong, G., "Issues in Forest Genetic Resource Conservation and Management," *Proceedings Ninth World Foresty Congress*, Mexico City, Mexico, July 1-10, 1985.

Namkoong, G.; and Selgrade, J.F.; "Frequency Dependent Selection in Logistic Growth Models," *Theoretical Population Biology*, (in press).

Pires, J.M., "The Forest Ecosystems of the Brazilian Amazon," *Tropical Forest Ecosystems*, Vendome, France UNESCO-UNEP, 1978, pp. 607-627.

Roughgarden, J., *"Theory of Population Genetics and Evolutionary Ecology: An Introduction,"* N.Y., MacMillan Publishing Co., 1979, 634 pp.

Selgrade, S.F.; and Namkoong, G.; "Stable Periodic Solutions for Two-Species, Density Dependent Co-Evolution," *Journal of Mathematical Biology* 22:69-80, 1985.

Contract Paper No. 9

International Institutional/Legal Frameworks for Ex-Situ Conservation of Biological Diversity

John Barton
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Office of Technology Assessment
U.S. Congress

This contract paper was prepared for the assessment of "Technologies to Maintain Biological Diversity." The views expressed are those of the author(s) and not necessarily those of OTA.

DEC 4 1985

INTERNATIONAL INSTITUTIONAL/LEGAL FRAMEWORK FOR EX-SITU CONSERVATION OF BIOLOGICAL DIVERSITY

prepared by:

John H. Barton
International Technology
Management
Los Altos, California

prepared for:

Biological Diversity
Assessment
FRR Program
OTA, U.S. Congress

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ABSTRACT

The paper reviews the international law and institutions governing the *ex situ* conservation of biological genetic diversity and defines important gaps and technical and political issues. The options for Congress are presented in a joint summary coauthored with Dr. Barbara Lausche.

The leading institution that has helped encourage and coordinate the global *ex situ* conservation of agricultural plant genetic resources is the International Board for Plant Genetic Resources (IBPGR), established in 1974 by the Consultative Group for International Agricultural Research, a consortium of countries, foundations, and international organizations.

Over the last several years, substantial political debate has arisen in this area. The debate, which is focussed in part on the IBPGR, goes to the terms and conditions under which genetic material is collected, transferred, and, in some cases, later used commercially. It also goes to the possible effect of plant breeders' rights on developing nations and on the conservation of genetic diversity. These rights derive from a patent-like legal protection for newly-bred varieties used in some nations, including the United States.

In large part as a result of this controversy, the Food and Agricultural Organization of the United Nations (FAO) has established a new political institution (a Commission) and a new agreement (an Undertaking) for plant genetic resources conservation. The United States has not accepted these new institutions; their relationship with the technically-oriented IBPGR will pose important future questions. Many in the international community would argue that it is wisest to avoid any political action in the area, in order to protect the technical and scientific character of IBPGR's work; others would look for possible compromises under which the United States could play a major role in the new institutions. And in any case, a working relationship between the IBPGR and these new institutions will be important to the coordination of *ex situ* and *in situ* conservation.

For areas other than plants, there are fewer international coordinating institutions. Such institutions might be considered for domesticated animals, and possibly in other areas -- and any new institutions should seek a better coordination between *in situ* and *ex situ* conservation. Finally, new international mechanisms for funding and for monitoring both types of institutions deserve consideration.

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John Barton

December, 1985

International Institutional/Legal Frameworks for ex situ Conservation of Biological Diversity

Genetic material has long been moved throughout the world so that each part of the world benefits from the conservation of genetic diversity in other areas. Conservation itself, however, is typically carried out at the national level. Hence there is need for an international institutional structure; this structure must fulfill several tasks:

1. Coordination of national programs to avoid unintended duplication and to avoid gaps in the species conserved. This requires a formal or informal international organization.
2. Encouraging nations to protect the genetic diversity that exists only within their borders. This may be done by official or unofficial political or diplomatic pressure; it may be formalized through international treaty.
3. Assurance that the conserved material is available for the global community. Sometimes this can be done by a scientific tradition; sometimes it requires a treaty.
4. Providing educational and scientific assistance to the smaller programs. This may be done by an international organization; it may be done through traditional scientific and educational exchange processes.
5. Providing financial assistance to the developing nation programs. This can be bilateral or multilateral.

Moreover, the international organizations and programs associated with economic development must themselves be responsive to genetic conservation concerns. (See Rich, 1985).

This paper reviews the current *ex situ* international institutional structure to determine how well it meets these tasks. It should be read together with Dr. Barbara Lausche's paper, which explores the parallel issues for *in situ* conservation, and with the joint summary of options for Congress to consider in strengthening this international structure.

I. Ex situ conservation of plant germplasm -- existing structure

The most active international institution for the *ex situ* conservation of genetic diversity is the International Board for Plant Genetic Resources (IBPGR), established in 1974 by the Consultative Group for International Agricultural Research, a consortium of nations, foundations, and international organizations, among them the Food and Agriculture Organization of the United Nations (FAO).

The IBPGR is a small group, whose secretariat is provided through the FAO. Its mission has been a coordinating one, of setting priorities and catalyzing the creation of a network of national programs and regional centers for the conservation of plant germplasm. It has provided training facilities, carried out research in techniques of plant germplasm conservation, supported some actual collection missions, and provided limited financial assistance for conservation facilities.

As envisioned by the IBPGR, collection was to be focussed on crop plants, based on priorities set by the Board and reflecting the economic importance of the crop, the quality of existing collections, and the risk that diversity in the field would disappear. The collected materials were to be kept in national programs, and duplicated outside the nation in which collected. There were to be global base collections for major crops and there were hopes of creating regional programs.

As measured both in its own terms and against the above list of objectives, the achievements of IBPGR are extremely impressive. Its network of base collections began in 1976 with 5 institutions. By 1984, allowing for negotiations in progress, the network included 35 institutions in 28 countries. As examples, for maize, there were regional collections in Japan, Portugal, Thailand, and the United States, and one in the Soviet Union was under negotiation. For rice, there were global collections in Japan and the Phillipines, and regional collections in Nigeria and the United States. (FAO, 1984) During the first ten years of the institution, new national programs were created in about 50 nations, and, by 1986, about 50 base collection centers are to have been designated for about 40 crops of major importance. (IBPGR, 1984) The program has limited itself to a particular group of plants, and has been highly successful in coordination, in encouraging national programs, and in scientific and educational assistance.

In part due to the success of IBPGR in focussing attention on the need to conserve genetic diversity, its work has given rise to political controversy. The IBPGR regards itself as a technical and scientific organization. A number of critics, however, regard the area as much more political. These critics regard the IBPGR as implicitly working for the corporate and agribusiness interests of the developed world and particularly of the United States. (Mooney, 1983; Westoby, 1985) The critics also argue that the current genetic material exchange system is inadequate to ensure that material will continue to be available, particularly to developing nations. The debate has become quite tendentious, with the proponents of the IBPGR (including most of those working professionally with _ex situ_ plant germplasm conservation in both developed and developing nations) emphasizing their scientific and pragmatic approach to the issue, and the critics of the IBPGR (including a number of academics, of FAO officials, and of developing nation political officials) emphasizing their fear that multinational corporations willl gain control over plant germplasm. Because many of the critics question the IBPGR's emphasis on _ex situ_ conservation, the coordination of _ex situ_ and _in situ_ conservation thus takes on political overtones that complicate the technical coordination of the two approaches.

These criticisms have led to the recent creation of new institutions to supplement the IBPGR. Before examining these institutions, it is wise to examine the criticisms more carefully. A large portion of the world's collected genetic material (but not usually the only copies) is, in fact, stored in the United States. This material is available under certain circumstances both to seed firms (who may incorporate the germplasm in varieties that they sell at a profit) and to public research institutions in both the developed and the developing world. (The primary limitation is that material is not made available from a base collection when it is available from a working collection elsewhere.) In 1977, however, a United States Department of Agriculture official stated that access to germplasm for some countries might be restricted for political reasons. (Mooney, 1983, p. 39) Moreover, although developing nations have -- with some exceptions -- been willing to allow seed collectors to obtain genetic material in their territory, the developed world seed firms will not necessarily share their advanced breeding material. Thus, it is argued, the current situation is unfair to developing nations. (Surenda, 1984) Supporters of the system respond that it actually provides an enormous amount of breeding material to developing nations, that the IBPGR system has been highly effective as an operation among scientists and has often replaced material lost from national germplasm collections, and that the United States has made clear that it strongly supports the free flow of germplasm. (CGIAR, 1982; Tucker, 1984; USDA, 1984) Moreover, there is no legal barrier to developing nations improving breeding material themselves instead of relying on developed-world seed firms. And the scientific community has often found informal methods, typically by routing the requests through third nations, to work around some of the few actual legal barriers to germplasm flow. (Tucker, 1984 and Ford-Lloyd, 1984).

The criticisms have also been based on the separate, but politically associated, issue of plant breeders' rights. Such rights, economically similar to patents, are used in the United

States and a number of other (mainly developed) nations to encourage innovation in plant breeding by permitting a monopoly on the new variety for a fixed period. (Barton, 1982; Berlan, 1985; Butler, 1983; Godden, 1984; Perrin, 1983). They do not, per se, affect the free flow of germplasm. They typically permit the protected material to be used for research and breeding purposes. Moreover, they limit use only in the nations in which rights have been actually obtained; there is no legal problem in using the same material in other nations. There is an international convention, the *Union pour la protection des obtentions vègètales* (2 December 1961), (UPOV) but this convention does not itself provide global protection. The parties to the convention, mainly developed nations, agree to enact plant breeders' rights legislation satisfying certain standards, and guarantee one another's nationals the right to obtain protection under their systems. Thus, a breeder seeking protection for a new variety will have to apply in each nation of interest, and will have no monopoly in nations that have issued no certificate.

Nevertheless, there has been serious concern about the impact of these laws on genetic diversity. A 1980 amendment to the United States legislation (PL 96-574, 94 Stat. 3350, 22 December 1980) was unexpectedly controversial; contemporaneous Canadian legislative proposals were defeated. Part of the concern is a fear of "privatization" of knowledge, as agricultural research shifts from public institutions to private institutions, and technology that was once freely available is instead offered only for a fee. Firms and public institutions may become less willing to share their germplasm with one another. Proponents of breeders' right respond that this trend is unavoidable, and that breeders' rights provide a form of protection that permits some exchange. The alternative, they suggest, is that firms would protect their material through trade secrecy, as, for example, by marketing only hybrids and maintaining close control over the parental lines -- an argument that rarely satisfies the critics. A second part of this concern is that breeders' rights encourage a private seed industry, and such a seed industry, it is argued, might be less responsive to genetic diversity than are public breeders. For example, private corporations might use a smaller variety of genes than public breeders and they might pay less attention to the possibility that their products will displace traditional local cultivars. Although there are undoubtedly some systematic differences between public and private breeding, and there may be need for preservation of local cultivars in both cases, it is hard to find persuasive reasons why a private breeding system will endanger genetic diversity more than a public one. Nevertheless, the actual trend of genetic diversity deserves careful monitoring, and there is also some reason for concern over the implications of the technical standards under which a variety is given breeders' rights protection. These standards include a uniformity requirement; thus there will be great genetic similarity among the different plants in one field. This is typical of some publicly-produced seeds as well. It may be better to use mixtures in both cases, or at least to seek availabilty of a number of genetically different varieties for farmers in any area.

This entire controversy helped catalyze a move toward deeper FAO involvement in the germplasm area, and toward a new international approach. (Tooze, 1984) The FAO argued that it should be taking the lead in plant genetic materials conservation; it could provide a framework for developing nations to obtain a greater political voice in the international conservation structure; it also argued that the IBPGR was not a formal public international organization, and would therefore have only limited legal ability to enforce a committment to make germplasm available. (FAO, 1983) This legal status argument can readily be questioned; IBPGR proponents also responded that the Board's technical emphasis works effectively, and is in fact an asset in surmounting political problems and dealing with nations outside the FAO.

As the alternative approach evolved, it consisted of an "Undertaking," and a new "Commission". The International Undertaking on Plant Genetic Resources, (FAO Conference Resolution 8/83, 23 November 1983) was negotiated within the framework of the FAO. (The United States and a number of other developed nations reserved their positions). The Undertaking was made non-binding, probably to increase the level of participation in such a controversial area. It calls for an international germplasm conservation network under the auspices of the FAO, states a duty of each nation to make all plant genetic material -- clearly defined to include advanced breeding material -- freely available, and calls for development of a procedure under which a germplasm conservation center can be placed under the auspices of FAO. Spain has requested such an arrangement (FAO, 1983). The

IBPGR would continue its current work, but that work would now be under the auspices of the FAO.

Although many nations have signed the Undertaking, a number have made reservations. Most of the explicit reservations turn on plant breeders' rights laws, but there have also been a number of other qualifications. (FAO, 1985a) It is certainly the case that some developing nations impose rather severe restraints on the export of germplasm, although rarely in basic crops like rice or maize. (Mooney, 1983, p. 39) Considering the more acrimonious debates about seeds and germplasm that have marked the last several years (and that may intensify as biotechnology poses new questions like the possibility of traditional patents on new forms of life), there is a serious risk that some developing nations will impose additional restraints on the export of germplasm.

The other part of the new FAO system is the Commission on Plant Genetic Resources, a group established by the FAO Conference to meet biannually to review progress in germplasm conservation. (FAO Conference Resolution 9/83, 23 November 1983) The Commission held its first meeting in March, 1985, with the United States present only as an observer. Much of the discussion focussed on the concerns expressed in the Undertaking and on issues that had regularly been dealt with by the IBPGR such as base collections, training, and information systems. In addition, however, the discussion and resolutions paid significant attention to _in situ_ conservation, and emphasized the importance of this area, which has received relatively less attention from the IBPGR. It is not yet clear whether a practical and cooperative division of responsibilities between the two entities can be developed, such as one based on differing emphases like *ex situ* vs. *in situ* or technical vs. political. (FAO, 1985b)

II. Ex situ *Conservation of animal and microbial germplasm -- existing structures*

On the animal side, there is practically no analogue to the IBPGR or to the controversy which has led to the FAO effort to build a parallel organization. The most significant international law is that deriving from treaties such as CITES and the World Heritage Convention discussed in Dr. Lausche's companion paper. There is some cooperation among zoos, and there may evolve a national level program of research, but this has been proposed, so far, in the area of wild animals rather than of domesticated species. (Dresser, 1985)

The existing programs can be expanded to provide international benefits and their extension to domesticated species should be particularly seriously considered. Even with the new technologies of artificial insemination and embryo transplant, reproduction rates for animals do not permit the spread of new varieties as rapidly as is possible with crop plants. Nevertheless, the entire developing world may be on the verge of adopting such new animal varieties, just as it adopted new cultivars during the Green Revolution. The same issues of the collection and conservation of traditional species, once posed for cultivars, may then be posed for livestock. Local breeds, which may have important resistance to local diseases, may thus disappear unless consciously conserved.

Congress should thus consider urging the creation of an international conservation program for livestock, presumably through a coordinating group with functions analogous to those of the IBPGR. (United States Agency for International Development, 1985; Gregory, 1984; Terrestrial Animal Species Panel, 1982) Such a group could be set up under the CGIAR, through the FAO, or through new institutional arrangements. The FAO has already developed a program and a series of conferences in this area, but the effort is much less far along than that described above for plants. (Collins, 1985; FAO, 1981; FAO, 1984a; FAO, 1984b; Hodges, 1984; Mason, 1981) The technology could perhaps rely on collections of animals themselves or, in some cases, on in situ techniques, but would probably emphasize storage of semen or embryos. (Dresser, 1985; Moulton, 1985).

Only in the microbial area is there a network comparable to that now in existence for plants. Repositories have evolved for a number of reasons ranging from research (Halliday & Baker, 1985) to patent law. In many patent systems, it is possible to obtain protection for use of a specific microorganism to produce a specific chemical product. But almost every patent law system requires an "enabling disclosure," that permits third parties to understand the invention, and, presumably, build on it. In this case, it is necessary to make the actual microorganism available; they are stored in international depositories. There has even emerged an international treaty under which each participant agrees to recognize deposit of a microorganism in a depository in another nation as adequate for patenting purposes. The treaty also sets standards and procedures for such depositories. ((Budapest) Treaty on the International Recognition of the Deposit of Microorganisms for the Purposes of Patent Protection, 1977 (32 U.S.T. 1241, T.I.A.S. 9768)). More important, there has evolved a coordinating system under the auspices of UNEP, UNESCO, and the International Cell Research Organization. (Halliday & Baker, 1985; Colwell, 1983) Under this MIcrobiological Resource CENter (MIRCEN) structure, unique to the microbial area, specific institutions undertake to preserve particular microorganism resources in perpetuity.

III. International gaps

The limitations of the existing international framework can best be discussed under three headings: gaps, technical problems, and political problems. Although there is some overlap, this division reflects the fundamentally different issues inherent in each area: relatively non-controversial institution-building in the first area, scientific and organizational coordination in the second, and sensitive politics in the third.

The gaps are the easiest to define. Whether the new organizations look more like the formal, political FAO, the less formal, less political IBPGR, or the informal MIRCEN, there may need to be new international institutional coverage of several important omitted *ex situ* areas. These include medicinal plants, certain of the more commercial plants such as rubber that IBPGR has deemphasized, the entire variety of animals, including wild and domesticated varieties, and possibly some marine species, for which commercial breeding techniques are beginning to evolve. (National Council on Gene Resources, undated) Expansion of IBPGR's responsibilities to non-crop plants would not be procedurally difficult; the Board's mandate extends to all plants, so that expansion would require only new funds and new human contacts to tap the appropriate expertise. For the other types of material, new institutions may be needed.

There may also be value in additional international exchange of information, particularly with respect to what is conserved in the smaller collections, such as those maintained by university faculty or private breeders. This interchange will often occur informally through working networks of researchers. In some cases, however, improved data management systems may be appropriate, and there may also be need for new mechanisms to maintain such collections, as, for example, when the interested researcher retires.

IV. Technical issues

Three types of technical issues deserve greater attention in the design and improvement of international germplasm conservation systems.

Quarantine

The techniques used for conserving and transporting plant and animal specimens will sometimes conserve and transport pathogens as well. (Moulton, 1985) Hence, unless one is very careful, the collection of seeds or embryos is also the collection of plant and animal diseases. A large integrated germplasm collection may therefore become a way to transport disease in space and time. Considering that pathogens may evolve at a different rate than their hosts, transportation in time may sometimes be as important as transportation in space.

One aspect of the issue is to ensure that quarantine restrictions (Kahn, 1985) not unreasonably restrict the flow of germplasm. A first look was taken at the problem in the mid-1970's and the FAO began a program to explore further, looking particularly toward creating a special phytosanitary certificate appropriate to the international transfer of germplasm. (There is already a treaty network that requires creation of inspection services and creates standards for these certificates, so that authorities of an exporting nation can certify that a particular shipment is free of certain pests, The International Plant Protection Convention, Rome, 6 December 1951, 150 UNTS 68, 23 UST 2769, TIAS 7465.) This program appears, however, to have suffered from lack of funds and attention. (Chiarappa, 1984; Hewitt, 1977) Congress might consider resurrecting it and encouraging further research and diplomatic attention to the area, perhaps looking to the emerging issue of animal germplasm transfer (Moulton, 1985) as well as to the traditional issue of movement of seeds and vegetative propagating materials..

There is also a separate question -- does the possibility of disease transmission imply that, at least for some categories of germplasm, global integrated genebanks should be avoided and _in situ_ or decentralized _ex situ_ strategies be used instead?

Congress might also encourage attention to this issue as it deals with national and international conservation strategies for different forms of germplasm.

The ex situ - in situ relationship

One of the most important needs is for better coordination of ex situ and in situ conservation. Each has its strong partisans; each has its own strengths and weaknesses with different risks of genetic drift and different economics. Sometimes, only one of these approaches will work. For some plants, for example, the seeds are almost impossible to preserve ex situ; for others, the pollinating insect must be preserved along with the seeds. The two forms of conservation can also contribute intellectually to each other. Often the experts on ex situ conservation can help define such parameters as the minimum size or the management parameters for an in situ reserve to ensure continued conservation of particular materials. And research in in situ reserves can help the ex situ conservationist estimate the portion of the diversity that has been collected. (Ingram, 1984)

The barriers here are institutional -- experts on ex situ conservation, centered around the IBPGR, tend to be in little contact with those on in situ conservation, centered around international environmental groups such as the IUCN and the WWF. One of the most beneficial possible programs for the new FAO Commission would be to help bridge this barrier. (FAO, 1985) There will probably have to be leadership institutions and certainly have to be technical working groups for particular species or groups of species. Congress may also wish to encourage such integration by seeking it at the domestic level -- the links between the two types of programs are nearly as distant within the United States as they are on the international institutional level, and building bridges at the domestic level would contribute to communication at the international level. This is a strong argument for strengthening the kind of coordination envisioned in the International Environment Protection Act of 1983 (Pub.L 87-195, Nov. 22, 1983).

Biotechnology

Although it is still early to predict the actual impact of biotechnology on genetic conservation, two likely effects can be noted. (See Peacock, 1984; Murray, 1982) First, biotechnology will permit new methods of conservation. The use of tissue culture for plant conservation, and possible use of embryo storage for animal conservation exemplify the first phase of this evolution. The ultimate conceptual possibility is storage of gene sequences rather than of organisms themselves.

Long before that point, there will be another important change -- a shift of focus (for economic applications only!) from organisms to genes. Ecological considerations may require concervation of whole organisms and ecosystems. For economic applications, however, it may become adequate to conserve any organism that has a gene for making, say, an unusual alkaloid, or governing an unusual physiological process -- and scientists will be able to put that gene into another organism as needed.

Ultimately, the genetic engineers will be able to design the new genes; for a long time they will probably want models from real organisms.

This will intensify the importance of germplasm conservation. It will also imply a need for greater understanding of the physiology of what is conserved -- for it is specific physiological mechanisms that will have to be conserved. This trend will probably also place a premium on conservation of the wide variety of organisms found in the soil, the tropics and the oceans and may even require greater emphasis on sampling and possibly preserving the diversity of hitherto nearly uncollected species such as insects. Both biotechnology effects will require close scientific links between genetic conservationists and other biologists -- and it will be important to make sure that these links are available for developing nation programs as well as developed nation programs. Moreover, there is a risk that with biotechnology the tension between developed and developing world will sharpen, for the commercial potential of the material and the genetic wealth of the developing world will both be clear.

V. Political issues

The political issues dominating international attention have been those associated with the criticism of IBPGR. But the financial issues may be as important.

Financial questions

Genetic conservation requires a long-term financial commitment. (FAO, 1983) Failure to maintain a reserve or a collection means that the world loses the money already spent (depending on the availability of the material in other areas) along with the future benefits of the lost diversity. Yet the prosaic and continuing tasks of maintenance and cataloguing will soon be the central need rather than the more exciting tasks of setting aside land or collecting species. The characterization of _ex situ_ plant materials is complex enough (Weeden, 1985); thinking about the comparable task for animal materials or for _in situ_ materials has hardly begun.

It is even more difficult for the international community than for a national government to guarantee long-term support, for international budgets are even more vulnerable than domestic ones. The IBPGR does not have enough funds to support the regular operating costs of developing nation genetic conservation programs. (IBPGR, 1984, p. 28) Yet, the developing nations are the least able to pay the costs of conserving genetic diversity, while the benefit of the resources is really for all humanity. At the same time, these nations wish responsibility for and control over the collections; as a matter of political reality, they must therefore face a share of the cost. Nevertheless, what is an international funder to do when it has laid down rules for its contribution and a nation indicates that it can no longer maintain a collection, because it needs the money to avert immediate starvation?

Congress may therefore wish to consider urging the creation of an international trust fund to assist in maintaining genetic reserves and collections. Ideally, such an organization would have an endowment, like a university or church, and would be able to tide the genetic resource over periods of weakened political commitment. A trust fund has already been established under CITES, an an interim approach to supporting the operation of its international secretariat (CITES 1979). The amounts involved in that case, however, are relatively small.

Beyond the financial cost of such a fund, the fund concept poses the question of choosing an appropriate degree of political independence. If a fund has too little independence, it is unable to protect genetic resources in times of international political disinterest; if it has too much independence, its reorganization and modification become difficult, even if it seriously errs. To justify support on any larger scale, Congress would undoubtedly insist that the share supplied internationally be well defined, that it be matched by contributions from other nations, and that there be exceptionally effective (and non-political) arrangments for control and auditing of the fund.

Whether or not such a fund is created, the international donor community will have to resolve the question of what happens when a nation committed to maintain a collection or reserve cannot afford to maintain it -- a question which is more than academic in today's time of debt and budgetary crises. The issue is an agonizing one; perhaps the right principle is that help should be extended in such circumstances only *in extremis* and only if the materials involved are genuinely made available to all humanity.

The free-flow and FAO/IBPGR issues

It is not yet clear whether Congress needs to act in the IBPGR/FAO controversy. It is quite possible that IBPGR, which has worked effectively in the past and has the support of many of the working scientists and donors, will continue to work effectively, in spite of the criticisms made in the FAO context -- and the new FAO Commission, which is seeking to be close to both the IBPGR and the range of non-governmental conservation groups, may prove a way to help integrate traditional *ex situ* and traditional *in situ* constituencies. Moreover, there will continue to be a practical international flow of germplasm (as there has been in the past), with or without the formal international arrangements envisioned by the FAO Undertaking. Thus, there is a strong argument for leaving the situation as is, ignoring the criticisms, and avoiding the risk that political action might upset effective scientific working arrangements.

The United States might, as an alternative, however, wish to associate itself with the FAO Commission and Undertaking, perhaps at the time of the next Commission meeting in 1987. Such steps might help strengthen developing-nation commitments to permit the free flow of germplasm, and reduce the risk that germplasm will more and more often be withheld as a bargaining chip for one or another favor. Unless Congress choses to eliminate plant breeders' rights in the United States, the United States would be unable to join the Undertaking without major reservation. Such a change of domestic law is politically unlikely; in making such a decision, Congress would in any event be most heavily influenced by its perception of the domestic benefits and implications of plant breeders' rights.

Although the plant breeders' rights issue is probably crucial to a number of nations supporting the Commission and Undertaking, there might be space for a compromise. Thus, Congress might build on recent executive affirmations of the free flow of germplasm by enacting legislation guaranteeing such export of germplasm against Export Administration Act restrictions or political embargos imposed for any other reason. Comparable provisions are already included in the Export Administration Act with respect to medicine and medical supplies. (50 U.S.C. App. § 2405 (g), as amended by PL 99-64, July 12, 1985) Support for breeding and biotechnology programs in developing nations might help. Or there might be ways to decrease any negative effects that plant breeders' rights might have on developing nations. For example, the conditions under which the equivalent of reasonable-royalty licensing is authorized (7 U.S.C. § 2404), currently restricted to certain situations of importance "in this country" might be expanded to include situations of international importance.

Should legislation be considered, it is crucial that the political debate not turn towards restrictions on the flow of germplasm for any reason whatsoever; any move in that direction would risk encouraging developing nation restraints on the future flow of germplasm. It should also be emphasized that the United States Department of Agriculture has recently committed itself quite strongly in favor of the free availability and exchange of germplasm, including the material in the National Plant Germplasm System. (USDA, 1984)

REFERENCES

Barton, J., "The International Breeder's Rights System and Crop Plant Innovation," *Science*, **216**: 1071-75 (1982).

Berlan, J., "Historical Analysis of Genetic Resources Valuation," prepared for OTA, July, 1985.

Butler, L.J. and Marion, B.W., "An Economic Evaluation of the Plant Variety Protection Act," (University of Wisconsin, December 1983).

Chiarappa, L. and Karpati, J.F., "Plant quarantine and genetic resources," *Crop Genetic Resources: Conservation & Evaluation* (Holden, J.H.W. & Williams, J.T. eds), London, George Allen & Unwin for International Board for Plant Genetic Resources, 1984, pp. 158-62.

Collins, N.M., "International Inventory and Monitoring for the Maintenance of Biological Diversity," prepared for OTA, July, 1985.

Colwell, R.R. "A World Network for Environmental, Applied, and Biotechnological Research," *ASM News*, vol. **49**, 1983, pp 72-73.

Conference of the Parties to the Convention on International Trade in Endangered Species of Wild Fauna and Flora, San Jose, Costa Rica, March 19 to 30, 1979, *Terms of Reference for the Administration of the Trust Fund for the Convention on International Trade in Endangered Species of Wild Fauna and Flora*, (Conf. 2.1), March, 1979.

Consultative Group on International Agricultural Research, *1982 Report on the Consultative Group and the International Agricultural Research It Supports; An Integrative Report*, (ICW/82/06; September, 1982).

Dresser, B.L., "Technologies to Maintain Animal Germplasm," prepared for OTA, August, 1985.

Food and Agriculture Association of the United Nations, "Animal genetic resources conservation and management," *Proceedings of the FAO/UNEP Technical Consultation*, FAO Animal Production and Health Paper No. 24, 1981.

Food and Agricultural Association of the United Nations, *Plant Genetic Resources, Report of the Director-General*, (C 83/25, August 1983) 45pp.

Food and Agricultural Association of the United Nations, Commission on Plant Genetic Resources, *Base Collections of Plant Genetic Resources*, CPGR: 85/4, December, 1984.

Food and Agriculture Association of the United Nations, "Animal genetic resource conservation by management, data banks and training," *Proceedings of the Joint FAO/UNEP Expert Panel Meeting, October 1983*, FAO Animal Production and Health Paper 44/1, 1984a.

Food and Agriculture Association of the United Nations, "Animal genetic resources: cryogenic storage of germplasm and molecular engineering," *Proceedings of the Joint FAO/UNEP Expert Panel Meeting, October 1983*, FAO Animal Production and Health Paper 44/1, 1984b.

Food and Agricultural Association of the United Nations, Commission on Plant Genetic Resources, *Future Work Program of the Commission*, CPGR/85/8, January, 1985.

Food and Agriculture Association of the United Nations, Commission on Plant Genetic Resources, *Country and International Institutions' Response to Conference Resolution 8/83 and Council Resolution 1/85*, CPGR/85/3, February, 1985a.

Food and Agriculture Association of the United Nations, *Report of the Commission on Plant Genetic Resources*, CPGR/85/REP, 1985b.

Ford-Lloyd, B. and Jackson, M., "Plant gene banks at risk," *Nature*, (letter), vol. **308**, p. 683 (19 April 1984).

Godden, D., "Plant breeders' rights and international agricultural research," *Food Policy*, pp. 206-18 (August, 1984).

Gregory, K.E., "Utilization and Conservation of Genetic Resources of Economic Animals," *Proceedings Symposium and Workshop on Genetic Resources Conservation for California*, April 5-7, 1984, pp. 6-7.

Halliday, J, and Baker, D. D., "Technologies to Maintain Microbial Diversity," prepared for OTA, July, 1985.

Hewitt, W.B., and Chiarappa, L., *Plant Health and Quarantine in International Transfer of Genetic Resources*, Chemical Rubber Company Press: Cleveland, 1977.

Hodges, J., "Review of the FAO/UNEP Programme on Animal Genetic Resources Conservation and Management," *Proceedings of the Joint FAO/UNEP Expert Panel Meeting, October 1983*, FAO Animal Production and Health Paper 44/1, p. 5, 1984.

Ingram, G.B. & Williams, J.T., "*In situ* conservation of wild relatives of crops," *Crop Genetic Resources: Conservation &*

Evaluation (Holden, J.H.W. & Williams, J.T. eds), London, *George Allen* & Unwin for International Board for Plant Genetic Resources, 1984, pp. 163-79.

International Board for Plant Genetic Resources, *The IBPGR in It's Second Decade; An Updated Strategy and Planning Report*, *(AGPG:IBPGR/83/151)*, Rome: IBPGR Secretariat, June 1984, 46 pp.

International Union for Conservation of Nature and Natural Resources, United nations Environment Programme, World Wildlife Fund, *World Conservation Strategy*, (VI. Priority Requirements: Genetic Diversity), 1980.

Kahn, R.P., "Assessment of Plant Quarantine Practices," prepared for OTA, July, 1985.

Mason, I.L., "Cooperative Work by FAO and UNEP on the Conservation of Animal Genetic Resources," *Proceedings of the FAO/UNEP Technical Consultation*, FAO Animal Production and Health Paper No. 24, p. 15, 1981.

Mooney, P.R., *The Law of the Seed*, (*Development Dialogue* 1983:1-2), 170 pp.

Moulton, W.M., "Constraints to International Exchange of Animal Germplasm," prepared for OTA, June 1985.

Murray, J.R, "Biological Diversity and Genetic Engineering," in Department of State, *Proceedings of the U.S. Strategy Conference on Biological Diversity, Nov. 16-18, 1981*, Washington, D.C., Department of State, 1982, p. 40.

National Council on Gene Resources, *Anadromous Salmonid Genetic Resources; An Assessment and Plan for California*, prepared for California Gene Resources Program, undated.

Peacock, W.J., "The Impact of Molecular Biology on Genetic Resources," in *Crop Genetic Resources: Conservation & Evaluation*, (Holdwin & Williams, ed., IBPGR, 1984) pp 268-76.

Perrin, R.K., "Some Effects of the U.S. Plant Variety Protection Act of 1970," (Economics Research Report No. 46, North Carolina State University, August, 1983).

Rich, B., and Schwartzman, S., "The Role of Development Assistance in Maintaining Biological Diversity In-Situ in Developing Countries," prepared for OTA, July 1985.

Surendra, L., "Seeds of disaster, germs of hope," *Far Eastern Economic Review*, 22 March 1984, pp 64-65.

Terrestrial Animal Species Panel, in Department of State, *Proceedings of the U.S. Strategy Conference on Biological*

Diversity, Nov. 16-18, 1981, Washington, D.C., Department of State, 1982, p. 70.

Tooze, S., "Safeguarding the pool," Nature, **308**, 8 March 1984, p. 105.

Tucker, W., "Seeds of Discord," Barron's, July 30, 1984, p. 26.

United States Agency for International Development, United States Strategy on the Conservation of Biological Diversity: An Interagency Task Force Report to Congress, February, 1985.

United States Department of Agriculture, Position Paper of the the United States Department of Agriculture on the International Plant Germplasm System, June 25, 1984.

Weeden, N.F. & Young, D.A., "Technologies to Evaluate and Characterize Plant Germplasm," prepared for OTA, June, 1985.

Westoby, Jack, "Genetic Erosion: the other war," IUCN Bulletin, p. 13, January/March 1985.

Contract Paper No. 10

International Laws and Associated Program for In-Situ Conservation of Wild Species

Barbara Lausche
World Wildlife Fund/Conservation Foundation

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Office of Technology Assessment
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FOR IN-SITU CONSERVATION OF WILD SPECIES

prepared by:

Barbara Lausche
Council, Public Policy
World Wildlife Fund-U.S.

prepared for:

Biological Diversity Assessment
FRR Program
OTA, U.S. Congress

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I

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INTERNATIONAL LAWS AND ASSOCIATED PROGRAMS FOR INSITU CONSERVATION OF WILD SPECIES

Introduction

Conservation of biological diversity encompasses both in-situ and ex-situ measures and, accordingly, both in-situ and ex-situ international laws and programs are involved. This paper reviews major international laws and associated programs that further in-situ conservation of biological diversity. It also notes some of the gaps and possible opportunities for strenthening existing mechanisms. For a full picture of the in-situ/ex-situ regime, this paper should be read jointly with its companion submission by John Barton on international laws and institutions dealing with ex-situ conservation. Options for Congress concerning in-situ and ex-situ issues flowing from these two papers are presented together in a separate synthesis paper by Barton and Lausche. 1

I. International Law

Public international law, the focus of this discussion, governs relations between countries as contrasted with private international law which is concerned primarily with relations between individuals. Public international law provides a variety of direct and indirect tools for insitu conservation of wild species. Most such laws contain biological diversity elements as aspects of broader conservation objectives commonly focussed on protection of single species, groups of species, or habitat. 2

The conservation sector of public international law is comprised of instruments carrying varying levels of binding obligation. The terms "hard" and "soft" law commonly are used to distinquish levels of legal significance (see, e.g., Lyster, 1985). "Hard" law refers to binding obligations reflected either in treaties or customary international law. "Soft" law refers to those instruments that do not have the force of a legally binding rule but, nevertheless, carry persuasive influence and policy guidance for state conduct. "Soft" law includes international declarations and resolutions arising from international conferences or work of international governmental organisations. Both "soft" and "hard" law instruments have relevance for biological diversity conservation.

The existence of an internationally recognized and established obligation related to conservation can be of substantial importance for in-situ maintenance of biological diversity at the national level. Increasingly, international convention obligations are providing national conservation authorities with the extra justification frequently needed to strengthen and modernize their national conservation programs. Particularly because of this growing role, international conservation conventions and associated soft law documents should be considered important legal and policy tools to be used increasingly in concert with other technical, administrative, and financial measures to encourage programs in in-situ conservation. 3

A. "Hard" Law--Treaties and other Agreements

In international law, a state has soverign authority over all natural resources within its territory. When a state ratifies a treaty, however, it voluntarily restricts certain of its rights, 4 assumes certain obligations, and derives certain benefits therefrom. Most international conservation conventions are concerned with some form of protected areas designation for habitat or with protection of specific species or groups of species in the wild. The early development of international conservation law was inspired largely by the interest in protecting large game mammals and birds. Less attention has been paid to in-situ conservation of wild flora, except where such species are indirectly protected through international traffic controls to protect commercial and agricultural plants from pest and disease (e.g., The International Plant Protection Convention, Rome, 1951). An exception is the new convention to control trade in endangered wild species of fauna and flora (CITES) discussed below.

At the global level, however, no convention exists solely for the conservation of genetic resources. The idea of a world treaty for conservation of genetic resources of wild species has begun to receive attention and is discussed in section III below. 5

The following four global instruments are among the most important for protection of flora, fauna and their habitats and have been called the "big four" wildlife conventions (Lyster, 1985). (For texts of the international and regional treaties noted in this paper, see, Burhenne, 1984, and for summaries of major environmental treaties, see, UNEP, 1984.). 6

1. The Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES), 1973, controls international wildlife trade in those wild species of plants and 7

animals that are listed as endangered or threatened in the three Appendices to the Convention. This convention has been called the most successful of all international treaties concerned with the conservation of wildlife, and with some 87 countries now Party to CITES there is justification for this claim (Lyster, 1985).

This convention has been reinforced particularly through national legislation in the United States. 1981 amendments to the Lacey Act (P.L. 97-79) prohibit import into the United States of wildlife taken or exported in violation of another country's laws. This U.S. domestic legislation gives support to other nations' efforts to conserve their own wildlife resources and, in conjunction with CITES, provides a powerful tool for wildlife conservation throughout the world that may have potential parallels in other aspects of biological diversity conservation. 8

2. The Convention on Wetlands of International Importance Especially as Waterfowl Habitat, ("Ramsar"), 1971, establishes a wetlands network and promotes the wise use of all wetlands and special protection for wetlands entered in a List of Wetlands of International Importance, entry contingent upon proposed sites meeting certain criteria. As of 1984, there were 36 Parties to the Convention and 294 wetland sites covering almost 20 million hectares included in its List of Wetlands of International Importance (Lyster, 1985). Once a site is included on the international list, the Party concerned has a legal obligation to implement plans that conserve the site (Article 3(1)). 9

3. The Convention Concerning the Protection of the World Cultural and Natural Heritage, 1972, establishes a network of 10

protected areas, provides a permanent legal, administrative and financial framework for identification and conservation of areas of outstanding cultural and natural importance. It establishes a World Heritage Committee, a World Heritage List, a List of World Heritage in Danger, and a World Heritage Fund to help achieve convention goals.

4. The Convention on the Conservation of Migratory Species of Wild Animals, 1979, commonly cited as the "Bonn Convention", provides strict protection for migratory species listed in Appendix I (in danger of extinction throughout all or a significant portion of their range), and encourages Range States to conclude "Agreements" for the conservation and management of Appendix II species (those in an unfavorable conservation status that requires or would benefit from international cooperation. As of 1984, 15 States were Party to the convention and a first meeting of the Parties in October 1985 has the task of setting up machinery for implementing the Convention. 11

Marine conservation also has received increased attention particularly in the past two decades. The Convention on the Law of the Sea, adopted in 1982 at Montego Bay and yet to come into force, identifies a number of general conservation obligations of relevance to in-situ conservation of biological resources, particularly those that are endangered with over-exploitation. Article 192 imposes a general obligation on States to protect and preserve the marine environment. Coastal states are obliged to ensure through proper conservation and management measures that the maintenance of the living resources in the exclusive economic 12 zone is not endangered by over-exploitation (Art. 61(2)). Activities outside national jurisdiction are to be undertaken "in accordance with sound principles of conservation" (Art. 150(b)).

The regional seas programs developed by the United Nations Environment Programme (UNEP) in cooperation with other agencies, particularly FAO and IMO, involve 10 regions [1] encompassing more than 120 of the world's approximately 130 coastal states. The objective of these programs is to reduce marine pollution and conserve living resources through cooperative efforts at pollution control and resource management. The legal mechanisms used to provide frameworks for such activities are "action plans" and regional conventions. The regional seas conventions commonly include articles on pollution from ships, aircraft, and land-based sources, pollution monitoring, and scientific and technological cooperation. The use of protocols is authorized in each convention text and these instruments address specific cooperative approaches to certain problems. Technical annexes provide specific standards for regulatory or cooperative activity. Oil pollution control already is addressed in protocols to most agreements. 13

Protocols are also being explored for protection of fragile ecosystems as well as habitats of depleted or endangered marine life through creation of marine protected areas. For example, The Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region, (Cartagena, Columbia, 1983), to which the United States is a party, is generating activity from both Governments and non-governmental conservation 14 organisations with respect to the possibility of protocols concerning specially protected areas and wildlife. Resolutions adopted when the Convention was open for signature call for preparation of draft protocols on such topics. (See, Convention, 1984). U.S. support could be a key factor in the ratification and implementation of such protocols (Curtis, 1985).

The Convention on the Conservation of Antarctic Marine Living Resources, 1980, is a special case for its important innovations in conservation of living resources. It obliges the Parties to adopt an ecosystem approach to exploitation of Antarctic marine living resources, thus requiring consideration of impacts on interdependent species and the marine system as a whole when setting harvest limits on target species. Article I(2) of the Convention defines marine living resources to include all species of living organisms, including birds, found south of the Antarctic Convergence. 15

Other regional treaties have emphasized nature conservation and species habitat protection through the creation of protected areas and other conservation programs. The major conventions in force are The Convention of Nature Protection and Wildlife Preservation in the Western Hemisphere, 1940; The African Convention on the Conservation of Nature and Natural Resources, 1968; The Convention on the Conservation of European Wildlife and Natural Habitats, 1979; and The ASEAN Agreement on the Conservation of Nature and Natural Resources, 1985. With habitat destruction being a principal cause of species extinction, treaties that call for protection of flora and fauna are 16 particularly important and need long-term support. The Western Hemisphere and African conventions, however, have had difficulties with national level implementation and enforcement, largely due to financial and technical limitations. The ASEAN Convention, being the most recent and involving extensive regional consultations to incorporate appropriate management and conservation techniques and safeguards, elicits high hopes for success.

Finally, a group of species-oriented treaties focus on controlling exploitation of specific wildlife, e.g., polar bears, vicuna, northern fur seals, whales, Antarctic seals (see, generally, Lyster, 1985). While these treaties primarily are concerned with taking controls, associated activities to protect habitat may serve biological diversity purposes as well. 17

These global and regional treaties offer important tools for use with long-term biological diversity conservation. At the same time, many inadequacies exist in the current regime. For some treaties, lack of adequate institutional machinery, a secretariat and budget, is a major drawback. Many of the treaties are difficult to enforce since incentives and disincentives are weak, leaving little recourse for retaliation if a country chooses to ignore its obligations. Some of the global conventions have too few non-European parties. Finally, in many developing countries, particularly, resources for implementation are scarce. 18

B. "Soft" Law

The United Nations Conference on the Human Environment held in Stockholm, Sweden in 1972 adopted a Declaration on the Human Environment that remains a key soft law document today. The 19

"Stockholm" Declaration contained 26 principles intended to serve as a guide for the international effort to protect the environment. Principle 2 speaks to conservation of the earth's biological resources:

> "The natural resources of the earth including the air, water, land, flora and fauna, and especially representative samples of natural ecosystems, must be safeguarded for the benefit of present and future generations through careful planning or management as appropriate."

In addition, the Stockholm Conference produced 106 recommendations in an "Action Plan" intended to represent tasks and guidelines to be adopted by Governments and international organisations in the future (United Nations Conference on the Human Environment, 1972). Recommendation 39 called upon Governments to agree to an international programme to preserve the world's genetic resources; this recommendation has been implemented most actively only with respect to ex-situ conservation of cultivated and domesticated materials.

A second important international soft law for conservation of 20
biological resources is the World Conservation Strategy (WCS). The Strategy is a comprehensive policy document prepared by the International Union for Conservation of Nature and Natural Resources (IUCN)--a network of governments, nongovernmental organizations, and individuals founded in 1948 to promote scientifically-based action for conservation. Advice, cooperation and financial assistance for preparation of the WCS were provided by the United Nations Environment Program and the World Wildlife Fund, with collaboration from FAO and Unesco.

The Strategy was launched worldwide in 1980 in more than 30 21 countries. It provides broad policy guidelines for determining development priorities to secure sustainable use of renewable resources, and linking conservation and development. The World Conservation Strategy has three principal objectives: maintenance of essential ecological processes and life-support systems, preservation of genetic diversity, sustainable utilization of species and ecosystems.

Introductory sections of the Strategy (IUCN, 1980) define conservation to be "the management of human use of the biosphere so that it may yield the greatest sustainable benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations". Development is defined to mean "the modification of the biosphere and the application of human, financial, living and non-living resources to satisfy human needs and improve the quality of human life". As defined and used in the World Conservation Strategy, conservation and sustainable development are mutually dependent processes. 22

A key WCS priority is the need for national level action through the preparation and implementation of national and, as appropriate, sub-national conservation strategies to implement the WCS's three objectives. These national level conservation planning tools are now finalized or in preparation in some 29 countries (see Appendix A). Their long-term purpose is to facilitate the integration of conservation in development planning according to ecological principles and, as such, provide an important tool to be supported and used at all stages of development. 23

The World Charter for Nature offers a third example of soft law that is becoming increasingly influencial in development. This document, the result of seven years of effort by international organizations and the United Nations, proclaims twenty-four principles of conservation by which all human conduct affecting nature is to be guided and judged. In 1982, the United Nations General Assembly, by a vote of 111 to 1, adopted the Charter sponsored by the Governments of Zaire and thirty-five other nations. 24

Most relevant among the Charter principles for biological diversity are the following:

> 2. The genetic viability on the earth shall not be compromised; the population levels of all life forms, wild and domesticated, must be at least sufficient for their survival, and to this end necessary habitats shall be safeguarded. 25
>
> ...
>
> 9. The allocation of areas of the earth to various uses shall be planned, and due account shall be taken of the physical constraints, the biological productivity and diversity and the natural beauty of the areas concerned. 26
>
> ...
>
> 14. The principles set forth in the present Charter shall be reflected in the law and practice of each State, as well as at the international level. 27
>
> ...
>
> 16. All planning shall include, among its essential
> elements, the formulation of strategies for the conservation 28
> of nature, the establishment of inventories of ecosystems and
> assessments of the effects on nature of proposed policies and
> activities; all of these elements shall be disclosed to the
> public by appropriate means in time to permit effective
> consultation and participation.

Other "soft law" documents include "Action Plans" and formal recommendations from international organizations, such as UNESCO Action Plan for Biosphere Reserves (see below), the IUCN Bali Action Plan and Recommendations resulting from the 1982 World 29

National Parks Congress and IUCN General Assembly Resolutions. Appendix B contains the Wild Genetic Resources Recommendation from the Bali Recommendations and the Genetic Resources and Biosphere Reserves Resolutions passed at the 16th Session of the General Assembly of IUCN in 1984.

II. Associated International Programs and Networks

In addition to treaties and soft law/policy instruments, two international programs, UNESCO's biosphere reserves and the Council of Europe's biogenetic reserves, are of direct importance for conservation of biological diversity. While these programs have not been established by international convention, they have received considerable official recognition at international and national levels probably because each governing body is active in building and overseeing its respective network. While still relatively new, they increasingly should provide valuable insights for parallel efforts elsewhere. A third international program, the Ecosystem Conservation Group, also is increasing its role in in-situ conservation work internationally and in developing countries. These three programs are the primary focus of this section. A fourth program, the proposed European network of representative ecological areas, is noted briefly. 30

Because of space limitations here and adequate coverage in other OTA papers, this section will not review again important international data collection programs such as UNEP's GRID, or IUCN's Conservation Monitoring Center activities. However, IUCN's environmental law data base will be briefly cited here because it 31 appears to have been missed elsewhere.

A. UNESCO's Biosphere Reserves

Unesco's Man and the Biosphere (MAB) Programme [2] launched in 1971, took as one of its major themes the "conservation of natural areas and the genetic material they contain" (MAB, Project 8). Under this theme, the concept of the biosphere reserve was introduced as a series of protected areas linked through a coordinated global network that could demonstrate the relationship between conservation and development. Since conception, building this network has formed a focus for implementing the Unesco MAB Programme through its national-level scientific committees. The first biosphere reserves were designated in 1976. Presently, the network consists of a total of 243 reserves in 65 countries (UNESCO, 1984). 32

In view of their joint interests, UNESCO, FAO, UNEP, and IUCN convened the First International Biosphere Reserve Congress in 1983 to review experiences and lessons learned todate and develop general guidance for future action. One result of the Congress was the preparation of the Action Plan for Biosphere Reserves which has three main thrusts: 1) improving and expanding the biosphere reserves network, 2) developing basic knowledge for conserving ecosystems and biological diversity, and 3) making biosphere reserves more effective in linking conservation and development, as envisioned by the World Conservation Strategy (UNESCO, 1984). 33

Successful and full application of the biosphere reserve concept, essentially a conservation and resource management tool, 34 has been difficult, partly because no formal legally-binding requirements or standards for designation and long-term protection exist. In addition, the concept in its fundamental form could be likened to a multi-use regional planning tool (ranging from core areas receiving strict protection to buffer zones in active agricultural or other compatible uses) with resource conservation for sustainable development as the overriding goal. Successful application of such a concept necessarily involves several levels of government as well as several agencies. Most government administrations are traditionally very sector-oriented and tend to be rather inexperienced sharing jurisdiction and program responsibilities of the nature probably required for an effective long-term biosphere reserve program. Recognizing this weakness, however, is the first step to fine-tuning project design and development assistance in ways that will facilitate increased coordination and cooperation across sectors.

35 Given the program's practical problems, the planning and management principles embodied within the biosphere reserves concept still reflect the essence of what an international program to conserve biological diversity needs to endorse. That is, "conservation as an open system" where areas of undisturbed natural ecosystems can be surrounded by areas of "symthatic and compatible use", and where people are considered part of the system (UNESCO, 1984).

B. Europe's Biogenetic Reserves and Proposed Ecological Areas 36

In 1976, the Council of Europe Committee of Ministers adopted Resolution (76)17 on a European Network of Biogenetic Reserves.

In 1977, a group of experts defined the procedural and institutional aspects of the network. The term "biogenetic reserve" was chosen because it reflects one of the major aims of the network--the conservation of the three main components of the biological environment: wild flora, wild fauna and soil--and stresses the importance of plant and animal genetic material to society (COE, 1977).

Resolution (76)17 recommends that States designate as biogenetic reserves any "protected area enjoying legal status and characterised by one or more typical, unique, endangered or rare habitats, biocenoses or ecosystems" (Annex, I(1)). Principle 7 in the Annex obliges each country to make an inventory of the different types of habitat, biocenosis or ecosystem and to establish a list of priority environments (heath, peatlands, etc.) for designation. Wherever possible, a biogenetic reserve should be surrounded by a buffer zone (Annex, III, Principle 3). An area becomes part of the network when accepted by the Committee of Ministers, on the recommendation of the European Committee for the Conservation of Nature and Natural Resources. To be included, legal protection must be stringent enough to conform with the principles of the Resolution although the area may retain its original terminology (e.g., park, protected landscape). 37

As of September 1985, 52 official biogenetic reserves exist, and hundreds have been proposed (COE, 1985). Up to two years may be required between the time a site is proposed and selected. Appendix C contains the list of current European biogenetic reserves. 38

The European region is also considering, through the Economic Commission for Europe, the creation of a network of representative ecological areas. The purpose of this network would include ensuring that the variety of natural types of the region would be identified and described so as to facilitate conservation of biological resources, including genetic resources (ECE, 1984). The network, currently at the proposal stage, would include biosphere reserves, biogenetic reserves, and other protected sites that qualified as representative ecological areas. 39

C. The Ecosystem Conservation Group

In 1975 the Ecosystem Conservation Group (ECG), comprised of FAO, UNEP, UNESCO, and IUCN, was established to coordinate the planning and execution of international conservation activities by the four organizations (UNEP, 1982). It is noted here because in recent months the ECG has taken a more active coordination role with in-situ conservation. At its 11th General Meeting, held in Rome in February 1984, the ECG agreed to institute an ad hoc Working Group on in-situ Conservation of Plant Genetic Resources (IUCN, 1985a). The Working Group consisted of FAO (lead agency), UNESCO, UNEP, IUCN, and IBPGR. The first meeting of the Working Group was held at IUCN Headquarters, Gland, Switzerland in April 1985, during the 12th General Meeting of the ECG. The charge to the Working Group was two-fold: 1) review on-going and planned activities in in-situ conservation in light of recommendations of the First Session of the FAO Commission on Plant Genetic Resources, UNESCO's Action Plan for Biosphere Reserves (see above discussion), and the IUCN Bali Action Plan; and 2) identify ways 40 to strengthen action and cooperation in response to these recommendations, with particular attention to improving information flow and promoting pilot demonstration activities (IUCN, 1985a).

At the first meeting of the ECG Working Group six major goals 41 for coordination and action were recognized and activities were identified within the framework of these goals (Appendix D). This development signifies an important step among the organizations to focus programmatically on plant genetic resources within a common action framework and, as reflected by the addition of the IBPGR, begin to build a mechanism to better integrate in-situ and ex-situ efforts.

D. IUCN's Environmental Law Information System

Since the early 1960's, one arm of the IUCN secretariat, the 42 Environmental Law Centre in Bonn, Federal Republic of Germany, has been indexing national and international environmental legislation worldwide. Some 20,000 titles are now part of the Centre's Environmental Law Information System (ELIS). In recent years, the Centre has developed a species law index that codes by scientific name protected species of wild fauna to the corresponding national legislation. This index is computerized, allowing manipulation by species, region, or country, and increasingly is a valuable data bank for program and policy planning by governments and non-governmental organizations when used in conjunction with scientific information about endangered species, ranges, and protection needs.

III. Gaps and Opportunities

For in-situ conservation, two issues seem among the most prominent with respect to the effectiveness of this array of international laws and programs. First, the debate is growing over the possible value of a global treaty specifically for biological diversity to fill what some perceive as a most serious gap in existing "hard" law. Second, what alternatives exist to the conventional protected area for in-situ conservation in order to provide protection beyond protected areas or at important sites where the traditional protected area is not feasible? 43

A. Another Global Treaty

In 1982, at the IUCN World National Parks Congress the notion of a world treaty on the conservation of genetic resources of wild species was proposed (C. de Klemm, 1984c). Since then, as awareness about biological diversity has grown so has the idea of a special treaty. Recently, a U.S. Government role towards this end also was recommended. A World Resources Institute report of recommendations for a U.S. strategy to conserve biological diversity in developing countries states that a "new international convention for the conservation of biological diversity is needed to ensure the cooperation of all nations, especially many of the developing countries ....The (United States Government) should begin efforts to develop a new international conservation convention and appropriate funding mechanisms to carry out its objectives and terms" (WRI, 1984). 44

The global treaty possibility is at a preliminary stage of conceptualization. Primary attention has been focussed on 45 bringing the idea forward in general terms to a level of credibility where interest could be generated for more detail. Two fundamental elements appear to be common among existing writings: a governing body and a fund, with an appropriate funding mechanism, to finance conservation action in developing countries. Certain key questions need research and evaluation at this point: first, whether existing treaties give "adequate" coverage to biological diversity issues; and second, if not, as proponents of a new treaty claim, whether a new global treaty could be adopted and enforced effectively within the timeframe required to address the problem. A subsidiary question relates to the effect of a new effort on the financial and technical resources that will continue to be needed for existing treaties and programs that currently play an important role in resource conservation.

As discussed above, existing mechanisms are comprehensive and 46 wide-ranging in several conservation sectors, all having value for biological diversity, some being more beneficial than others. In many cases, existing conventions were adopted because of some specific tangible appeal (a particular species, a valuable habitat) which would seem to facilitate their implementation. (In contrast, biological diversity is not yet a tangible topic to many policy-makers). Even with this advantage, existing treaties exhibit basic weaknesses in implementation because of lack of adequate administrative machinery (e.g., well-funded and staffed Secretariats), lack of financial support for on-the-ground programs (e.g., equipment, training, staff for national conservation, wildlife, and agricultural departments), and lack of reciprocal obligations that serve as incentives to comply (C. de Klemm, 1984c). A possible exception is CITES, the convention controlling trade in endangered species, which has mechanisms to facilitate reciprocal trade controls and a technical Secretariat, although inadequately funded. The Bonn Convention (migratory species), only beginning to come into force, also has a much-needed, though small Secretariat.

Whether a new treaty could be adopted and put in force in the present global political environment is likely to hinge on the amount of financial and other resources available as incentives to countries to ratify. Historically, a regional approach to conservation treaties has seemed to dominate, probably because the likelihood of consensus among states of a region with similar problems is greater. The scope of a new treaty also probably would affect its success. The Convention on the Law of the Sea, as a global treaty of major scope, provides an example where incentives have not seemed adequate to date to balance obligations for the United States, for example, concerning deep seabed mining. At the same time, the U.S. has declared as national ocean policy its intention to comply with non-seabed mining issues in a manner consistent with the Convention (The White House, 1983). Nevertheless, the U.S. position not to ratify probably is influencing the position of other western countries and, as such, is having an impact on the process and speed with which implementation is occurring. 47

B. Protected Areas and Beyond

As noted above, the creation of protected areas is the 48 conventional conservation approach in most international laws and programs furthering biological diversity. The modern interpretation of protected areas includes the full-range of conservation purposes, from strict protection to multiple use, e.g., biosphere reserves (IUCN, 1978). This evolution of the traditional "strictly protected park" opens opportunity for more flexible uses of the concept with land, coasts, and water. Marine parks (see, e.g., Salm, 1984) are one of these uses that has received impetus from programs such as UNEP's regional seas. International marine protected areas also might be increasingly explored. For example, biological diversity proposals might build upon the United States' deep seabed mining "stable reference areas". These areas are to be used as references zones for resource evaluation and environmental assessment. The concept would include the designation of appropriate zones to insure a representative and stable biota of the deep seabed (The Deep Seabed Hard Minerals Resources Act, 1980, P.O. 96-283, Sec. 109(f)) (see, also, National Resource Council, 1984). These innovative and increasingly flexible uses for protected areas need serious consideration and support as new problems and goals emerge in biological diversity conservation worldwide.

In addition, the question of alternatives and supportive measures outside protected areas is becoming a growing concern. The 1984 State of the Environment Report of the Organization for Economic Cooperation and Development (OECD), for example, urges that protected areas are not enough. Also needed are environmentally sensitive policies for habitat on non-designated lands (OECD, 1985).

50 Even where protected areas exist as effective tools for conservation of biological diversity, at least four additional tools of development are needed in a country to preserve its resources. These are: 1) land use and development planning controls, 2) toxic and other environmental pollutant controls, 3) species trade controls, and 4) control over introduction of harmful exotic species. Where protected areas no longer effectively exist or are not feasible, these tools are even more urgently required. Development assistance projects could facilitate and encourage the introduction and strengthening of such measures as an integral part of the project process.

51 Of these tools, land use planning seems to have particular potential for increased consideration in conservation. The FAO Commission on Plant Genetic Resources at its first session (Rome, March, 1985) stressed "the need to consider in situ conservation activities within the framework of overall land use planning and within the context of prevailing socio-economic conditions" (FAO, 1985). Cyrille de Klemm, in a recent article on genetic diversity outside protected areas, explored a number of land use control options that could be used to a greater extent in conservation and development (1984b, see also 1984a). Where private land is involved, general land-use controls could be enforced through general protection orders that impose restrictions on land use, or a permitting system. These are common tools already used for nature conservation and environmental protection in many western countries, particularly in Europe. A requirement for a permit

could apply to all activities likely to harm certain natural habitats or ecosystems, e.g., wetlands, coastal marshes, rivers. This approach requires legislation to authorize the requirement, procedures, the kinds of conditions that might be imposed, and activities that might constitute exceptions to the permit requirement.

Non-statutory protection of specific sites might be achieved through voluntary protection agreements between the landowner and conservation authorities. Usually such agreements are most attractive when the landowner is offered certain incentives, e.g., tax subsidies or deductions, for preserving certain sites. 52

Programs to preserve areas where only small natural or semi-natural sites remain, for example, within cultivated fields, also are important. Such efforts can help maintain at least a minimum amount of natural vegetation in hedgerows, tree groves, riparian areas, etc. Zoning ordinances could become a powerful conservation tool if extended not only to construction but to all changes in land-use, including agriculture. Giving conservation advice to farmers about the value of protected landscapes on the countryside for biological diversity and other purposes would be an important component of such controls.

Whether land is public or private, however, in many countries the land management agency(ies) has little or no authority to oversee other agency activities and veto actions that would be detrimental to maintaining the naturalness of the land. While a growing variety of land use planning experiences and tools are available for consideration, the prerequisite for using these 53 tools wisely is strenthened technical capacity to identify, inventory, and monitor (along with legal authority to protect) valuable natural areas.

Thus, in programs for biological diversity conservation, limitations such as these require complementary efforts in ex-situ conservation. Finding the necessary balance of emphasis between in-situ and ex-situ conservation for each case is key. The First Session of the FAO Commission on Plant Genetic Resources discussed the need to build this integration through, for example, the establishment of national centres on in-situ conservation of plant genetic resources that would be closely linked to the ex-situ gene banks on the one hand and to the protected area management on the other (IUCN, 1985b). Such proposals will require increased cooperation at international and national levels, along with creative use of existing laws and programs to meet these emerging management and scientific needs. 54

IV. Conclusion

A principal need in all existing economic development programs is better integration of conservation and development activities. Notable advances have been made since the Stockholm Declaration of 1972 in the creation and implementation of international laws, policies (soft law), and programs for conservation. This paper has identified the major developments, most of which have come into being since the early 1970's. These tools, if used to their fullest, provide a broad policy framework, even with existing gaps, that has potential for substantially 55 increased conservation activity within the present system. Moreover, to the extent financially and technically feasible, developing country leaders seem to be taking a more active and serious interest in the programs.

Ironically, now that awareness is increasing in the third world, the critical financial and technical support needed from developed countries appears to be lagging behind. . In particular, the commitment of the U.S. toward conservation as an interdependent element of development is unclear. This country has taken no concrete measures to consider preparation of a national conservation strategy, for example, even as many western and developing countries move forward in this area (e.g., the United Kingdom, Switzerland, Australia, Mexico). It struggles each year to approve relatively meager and, in some cases, shrinking budgets for the United Nations agencies that work in environmental protection (notably, UNEP, WHO, FAO, UNESCO). 56

Concerted U.S. action is needed to reverse this trend of seeming neglect for conservation elements of development. As a major economic and political power worldwide, the U.S. could undertake initiatives and lead the way for other countries. Important measures are needed in national policy-making, development guidance, research, and technical assistance in order to sustain and strengthen beneficial existing international programs and, as required, create new activities to meet national and global conservation needs, including those for conservation of biological diversity. 57

NOTES

1. The ten regions are the Caribbean, Mediterranean, Persian Gulf (Kuwait Action Plan Region), West and Central Africa, East Africa, East Asia, Red Sea and Gulf of Aden, South Pacific, South-East Pacific, South-West Atlantic.

2. The UNESCO Man and the Biophere (MAB) Programme is a worldwide program of international scientific cooperation that supports research, training, and field investigation. Research under the MAB program focusses on understanding the structure and function of ecosystems and environmental impacts of different types of human intervention. The program involves disciplines from the social, biological and physical sciences, is supervised by the International Coordinating Council, and tied to the field through national-level scientific MAB committees.

BIBLIOGRAPHY

Burhenne, W.E., *International Environmental Law--Multilateral Treaties Series (Vols. I-IV)*, Berlin, Federal Republic of Germany: Erich Schmidt Verlag, 1984, with regular update service.

Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region, in "Message from the President of the United States to the 98th XCongress, 2nd Session; Treaty Doc. No. 98-13, 1984, Washington, D.C.: U.S. Government Printing Office, Resolution on Protected Areas and Wildlife at 42.

Council of Europe (COE), *Resolution (76)17 On the European Network of Biogenetic Reserves and Annex*, adopted by the Committee of Ministers on 15 March 1976 at the 225th meeting of the Ministers' Deputies, Strasbourg, France: Council of Europe. 1976, 3 pp.

Council of Europe (COE), "Secretariat Memorandum on European Network of Biogenetic Reserves," Strasbourg, France: Council of Europe, 1977, 5 pp.

Council of Europe (COE), Jean-Pierre Ribaut's office, Strasbourg, France, personal communication, 9/1985.

Curtis, C., President, The Oceanic Society, Washington, D.C., personal communication, 9/1985.

de Klemm, C., "Conservation of Species: The Need for a New Approach," *Environmental Policy and Law* 9:117-128, 1982.

de Klemm, C., "Conservation of Wetlands, Legal and Planning Mechanisms," in *Proceedings of the Conference of the Contracting Parties to the Convention on Wetlands of International Importance Especially as Waterfowl Habitat, Groningen, 1984*, Gland, Switzerland: International Union for the Conservation of Nature and Natural Resources, pp. 219-246, 1984a.

de Klemm, C., "Preserving Genetic Diversity Beyond the Limits of Protected Areas: A Legal Review," Bonn, Federal Republic of Germany: IUCN Environmental Law Center, 1984b, 19 pp., (unpublished).

de Klemm, C., "Protecting Wild Genetic Resources For the Future: The Need for a World Treaty," in *National Parks, Conservation, and Development--The Role of Protected Areas in Sustaining Society, Proceedings of the World Congress on National Parks, Bali, Indonesia, 11-22 October 1982*, National Parks, Bali, Indonesia, 11-22 October 1982, Washington, D.C.: Smithsonian Institution Press, 1984c, pp. 661-667.

Economic Commission for Europe, "Possible Promotion of a Network of Representative Ecological Areas--Report of the Chairman of the Task Force Established by the Senior Advisers to ECE Governments on Environmental Problems", United Nations Economic and Social Council, 13 December 1984, Doc. ENV/R.170

Food and Agriculture Organization (FAO) of the United Nations, "First Session of the Commission on Plant Genetic Resources, Rome, 11-15 March 1985", Rome: FAO.

International Union for Conservation of Nature and Natural Resources (IUCN), Categories, Objectives and Criteria for Protected Areas, Gland, Switzerland: IUCN, 1978.

International Union for Conservation of Nature and Natural Resources (IUCN), "Recommendations of the World National Parks Congress," in National Parks, Conservation, and Development--The Role of Protected Areas in Sustaining Society, Proceedings of the World Congress on National Parks, Bali, Indonesia, 11-22 October 1982, Washington, D.C.: Smithsonian Institution Press, 1984a, pp. 765-776.

International Union for Conservation of Nature and Natural Resources (IUCN), "Report of the First Meeting of the ECG Working Group on In Situ Conservation of Plant Genetic Resources, 11-12 April 1985," Gland, Switzerland: IUCN, 1985a.

International Union for Conservation of Nature and Natural Resources (IUCN), "Report on IUCN's Participation in the First Session of the FAO Commission on Plant Genetic Resources, Rome, 11-15 March 1985", Gland, Switzerland: IUCN, 1985b, 8 pp.

International Union for Conservation of Nature and Natural Resources (IUCN), "Resolutions of the 16th Section of the General Assembly of IUCN, Madrid, Spain, 5-14 November 1984," Gland, Switzerland: International Union for Conservation of Nature and Natural Resources, 1984b, 20 pp.

International Union for Conservation of Nature and Natural Resources (IUCN), World Conservation Strategy, Gland, Switzerland: IUCN, 1980.

Lyster, S., International Wildlife Law, Cambridge, Grotius Publications, Ltd., 1985, 470 pp.

Organization for Economic Cooperation and Development (OECD), 1984 State of the Environment Report, Paris, France: OECD, 1985.

National Research Council, Deep Seabed Stable Reference Areas--Report of a Study, Board on Ocean Science and Policy, Washington, D.C.: National Academy Press, 1984, 74 pp.

Salm, R., Marine and Coastal Protected Areas: A Guide for Planners and Managers, Gland, Switzerland: International Union for Conservation of Nature and Natural Resources, 1984, 301 pp.

The White House, "Statement by the President on United States Oceans Policy, March 10, 1983", Washington, D.C.: Office of the Press Secretary.

United Nations Educational Scientific, and Cultural Organization (UNESCO), "Action Plan for Biosphere Reserves," in Nature and Resources XX(4): 11-22, 1984.

United Nations Educational, Scientific, and Cultural Organization (UNESCO), Expert Panel on Project 8: Conservation of Natural Areas and of the Genetic Material They Contain, Morges, September 1973, Paris, France: UNESCO.

United Nations Environment Programme (UNEP), Register of International Treaties and Other Agreements in the Field of the Environment, Nairobi, Kenya: UNEP, 1984.

United Nations Environment Programme (UNEP), "UNEP and Protected Areas--Review of Joint Activities Carried Out By UNEP and FAO, IUCN and the UNESCO MAB Programme 1973-1982," paper presented at the World National Parks Congress, Bali, Indonesia, 11-22 October 1982, Nairobi, Kenya: United Nations Environment Programme, 1982, 32 pp.

United Nations Conference on the Human Environment, "Declaration on the Human Environment," in Keesing's Contemporary Archives, September 16-23, 1972, pp. 25476-25479.

United Nations, The World Charter for Nature, Resolution of the General Assembly adopted on October 29, 1982, New York: United Nations General Assembly.

World Resources Institute (WRI), Recommendations for a United States Strategy to Conserve Biological Diversity in Developing Countries, Washington, D.C.: World Resources Institute, 1984, 83 pp.

Appendix A: Countries Where National Conservation Strategies Exist or are Being Prepared

- Australia
- Bangladesh
- Belize
- Botswana
- Fiji
- Guinea Bissau
- Jordan
- Italy
- Ivory Coast
- Madagascar
- Mexico
- Nepal
- Netherlands
- New Zealand
- Pakistan
- Panama
- Philippinnes
- St. Lucia
- Senegal
- Seychelles
- Sierra Leone
- South Africa
- Sri Lanka
- Switzerland
- Togo
- Uganda
- United Kingdom
- Zambia
- Zimbabwe

Source: M. Halle, International Union for Conservation of Nature and Natural Resources: Gland, Switzerland, personal communication, 9/1985.

Appendix B: Examples of "Soft Law"--Recommendations and Resolutions on Matters Concerned with Conservation of Biological Resources.

I. Recommendation No. 10 from the World National Parks Congress, Bali, Indonesia, 11-22 October 1982:

10. CONSERVATION OF WILD GENETIC RESOURCES

BEARING IN MIND that protected areas have the potential to play key roles in the preservation of the genetic diversity of wild species;
AWARE that wild genetic resources already make an important contribution to agricultural production and provide raw materials for the pharmacological industry and, through breeding, for aquaculture and silviculture;
CONCERNED that wild populations of value as genetic resources are being lost to habitat destruction and other pressures;
CONSCIOUS that the primary means of safeguarding wild genetic resources for present and future use must be *in situ* in protected areas because of their great diversity, the difficulty of maintaining certain of them *ex situ*, and the need to conserve them as populations co-evolving with the ecosystems of which they are a part;
MINDFUL THAT existing networks of protected areas provide the framework for a system of *in situ* gene banks;

The World National Parks Congress, meeting in Bali, Indonesia, October 1982:
CALLS UPON governments and international institutions to:

a) make the conservation of wild genetic resources an explicit objective of protected area systems and provide for the establishment of *in situ* gene banks;

b) review the extent to which wild genetic resources are adequately maintained by existing protected area systems;

c) make and implement plans for the establishment of *in situ* gene banks, including as appropriate the zoning of existing protected areas and the designation of new ones;

REQUESTS that IUCN take a more prominent role in preparing and disseminating inventories of wild species and populations of known or likely value as genetic resources, to assist nations wishing to establish *in situ* gene banks;
REQUESTS that national and international governmental and non-governmental agencies cooperate in the preparation of such inventories, and allocate resources for the establishment of *in situ* gene banks; and
INVITES IUCN to investigate the possible development of international instruments to regulate the commercial exploitation of wild genetic resources.

II. Resolutions No. 24 and 32 from the 16th Session of the General Assembly of IUCN, Madrid, Spail, 5-14 November 1984:

16/24. WILD GENETIC RESOURCES AND ENDANGERED SPECIES HABITAT PROTECTION

RECOGNIZING that genetic processes are natural biological phenomena which are actuated by the genetic material present in wild animal and plant species and which may be put to use by mankind in scientific and technological applications;

FULLY CONSCIOUS that wild plant and animal species in all their genetic diversity constitute a vast and virtually untapped reservoir of innumerable, irreplaceable genetically controlled processes of immense value to mankind now and in the future;

RECOGNIZING that these processes by their very nature cannot be the subject of exclusive or proprietary rights on the part of any state or individual;

ACKNOWLEDGING that these processes form part of the common heritage of mankind and that they should be and remain available to present and future generations;

DEEPLY CONCERNED by the increasing rate of human destruction of natural habitats, wild species and the genetic resources they contain, especially in regions such as the Mediterranean, the Himalayan and nearly all tropical regions;

ALARMED that the rate of species extinction has now far outstripped natural extinction rates to the point where a large number of species will be lost by the year 2000;

RECOGNIZING the responsibility of stewardship towards all other life forms on this planet that rests upon humankind and the inalienable rights of species to exist;

CONVINCED that the preservation of this heritage can in most cases best be achieved by in situ conservation;

RECOGNIZING that costs incurred for the conservation of wild genetic resources should be shared and, in particular, that commercial users of the processes generated by these resources must contribute to these costs;

RECALLING Recommendations 39, 40 and 93 of the 1972 United Nations Conference on the Human Environment and the relevant work of UNEP and Unesco, as well as of FAO, in particular the International Undertaking on Plant Genetic Resources adopted by the 22nd Session of FAO General Conference on 23 November 1983;

FURTHER RECALLING Resolution 15/10 adopted by the 15th Session of the IUCN General Assembly in Christchurch, New Zealand, 11-23 October 1981 and Recommendation 10 of the World Congress on National Parks, Bali, Indonesia, 11-22 October 1982;

The General Assembly of IUCN, at its 16th Session in Madrid, Spain, 5-14 November 1984:

1. REQUESTS the Director General of IUCN, after having evaluated current proposals for international action, to promote the implementation of the following principles which should also serve as a basis of a preliminary draft for a global agreement on the conservation of the world's wild genetic resources with a view to developing a joint draft by late 1985;

   (a) Wild genetic processes are both renewable and non-renewable, they must be maintained because they are the basis of ecological diversity. Access to wild genetic resources should be unrestricted for the purpose of pure or applied research, breeding and conservation. Where access to genetic material involves the collection of individual specimens of species from the wild, such collection must be subject to strict regulation so as not to operate to the disadvantage of the species.

   (b) The world community has the responsibility to preserve these resources for future generations, States, as the custodians of these resources, have a duty of stewardship for those wild genetic resources under their jurisdiction or control.

   (c) Conservation measures taken in pursuance of this duty should aim primarily at preserving wild genetic resources in situ and should include the adoption and implementation by Governments of legislation for the conservation of natural habitats, and particularly the habitats of endangered species, as well as long-term management plans for these species and their habitats. These measures should also make appropriate provision for training.

   (d) Financial resources necessary to implement these conservation measures shall be made available through contributions (such as those described in subpara(e) below, through other contributions by States or through other means) to those States that protect wild genetic resources in situ in the interest of mankind and cannot afford to do it alone.

   (e) In particular, commercial users of processes derived from wild genetic resources have to participate in these conservation efforts through financial contributions towards the costs incurred by individual States in the fulfilment of this duty.

16/32. BIOSPHERE RESERVES

CONSIDERING that biosphere reserves play an increasingly important role in conserving representative ecosystems and their biological diversity;

CONSIDERING that biosphere reserves, through their multiple functions, serve as practical focal points for local, regional and international cooperation to address inter-related ecological, land use and socio-economic problems;

CONSIDERING that biosphere reserves aim at developing support from local populations for long-term conservation efforts;

NOTING that the international network of biosphere reserves now contains 226 sites in 62 nations;

NOTING FURTHER that the proposals for action endorsed by the First International Congress on Biosphere Reserves, held in Minsk in the Soviet Union in 1983, provide a framework for the further development of this international network;

CONSIDERING that the concept and development of biosphere reserves is of considerable importance in the implementation of the World Conservation Strategy;

NOTING that an international Action Plan on Biosphere Reserves is now being developed for early adoption by the Co-ordinating Council of the Programme on Man and the Biosphere, and that this Action Plan will be considered by the governing bodies of UNEP, FAO and Unesco;

The General Assembly of IUCN at its 16th Session in Madrid, Spain, 5-14 November 1984:

1. WELCOMES the expansion, consolidation and functional development of the international network of biosphere reserves;

2. REQUESTS the Director General to ensure that scientific and technical support is given by IUCN to the finalization of the Action Plan on Biosphere Reserves, and to its implementation, as a matter of urgency;

3. INVITES all IUCN components to enhance the role of biosphere reserves in programmes for ecosystem conservation and integrated rural development, and to acknowledge the forthcoming Action Plan on Biosphere Reserves as a major contribution towards the World Conservation Plan.

Appendix C: European Biogenetic Reserves

Appendix D: Goals and Proposed Actions of the Ecosystems Conservation Group

TOWARDS A COORDINATED WORK PROGRAMME FOR
IN SITU CONSERVATION OF PLANT GENETIC RESOURCES

Goal 1 TO RAISE AWARENESS OF THE IMPORTANCE OF IN SITU CONSERVATION

Objective 1.1 AMONG DECISION-MAKERS, SCIENTISTS AND LAND-USE PLANNERS

Activities

1.1.1 To prepare an information document on in situ conservation of plant genetic resources (UNEP, drawing upon existing material. To be considered by Ad Hoc Group, a draft if possible for next meeting of ECG).

1.1.2 To continue and strengthen existing newsletters and journals on Plant Genetic Resources (e.g. FAO/IBPGR's Newsletter, FAO's Forest Genetic Resources).

1.1.3 To further develop the IUCN Threatened Plants Newsletter, possibly under a new title, as a magazine on plant conservation for scientists (IUCN).

1.1.4 To increase the flow of information on Plant Genetic Resources in other magazines, journals and newsletters, such as Unesco's Nature and Resources, and Infomab, UNEP News, FAO's Unasylva, IUCN's Bulletin (ECG members plus IBPGR).

Objective 1.2 AMONG WIDER AUDIENCES.

Activities

1.2.1 To build on the IUCN/WWF Plants Campaign with a systematic substantial ongoing awareness campaign on conservation of Plant Genetic Resources. (Closely co-ordinated with activities in the FAO International Year of the Forest and IUBS Decade of the Tropics) (ECG members plus IBPGR).

Goal 2 RESEARCH ON WILD PLANTS AND THEIR IN SITU CONSERVATION

Objective 2.1 IDENTIFICATION OF GENE POOLS AND WILD SPECIES WITH SIGNIFICANT GENETIC RESOURCES

Activities

2.1.1 Encourage countries to identify priorities in *in situ* conservation and encourage the preparation of national inventories (ECG partners).

2.1.2 Identify and develop international and/or regional priorities on:

1. Food crops (IBPGR)
2. Woody species (FAO)
3. Forage species (IBPGR, FAO)
4. Medicinal plants (WHO)
5. Others, e.g. ethnobotanical species (IUCN)

(Overall co-ordination by IUCN and UNEP, in close co-operation with Unesco, FAO, WHO and IBPGR.)

2.1.3 To continue identification of threatened taxa around the world (IUCN/FAO).

Increased emphasis on groups with high percentages of useful and economic species, e.g. palms (funded by WWF-US, just started for Americas), trees, Gramineae, Leguminosae, Orchidaceae.

2.1.4 Taxonomic clarification for wild mango (completed) and okra (ongoing) (IBPGR-IBPGR funded.)

2.1.5 Promote additional new taxonomic work in key taxa.

Objective 2.2 INVENTORIES OF THE GENETIC RESOURCES OF PARTICULAR REGIONS AND PROTECTED AREAS; SURVEYS OF THE INTRA-SPECIFIC VARIABILITY OF VALUABLE GENE POOLS AND RELATED ECOLOGICAL AND ENVIRONMENTAL FACTORS WHICH SUSTAIN IT ("ecogeographical surveying" and "genecological surveying")

Activities

2.2.1 Begin development and standard methodology for inventory and survey (FAO, IBPGR in co-operation with Unesco).

2.2.2 Ecogeographical survey of some wild relatives of crops and forages in the Sahelian Region (ongoing IBPGR - IBPGR funded).

2.2.3 Ecogeographical survey of some wild species with genetic resources in Europe (including Turkey) (recently approved - IBPGR in cooperation with IUCN/Unesco - funding from IBPGR/UNDP).

2.2.4 Ecogeographical survey of *Acacia* and *Prosopis* species (ongoing - FAO in co-operation with Unesco - FAO funded).

Objective 2.3 DEVELOPMENT OF METHODOLOGIES FOR MONITORING AND MANAGING TARGET POPULATIONS AND ASSOCIATED ECOSYSTEMS

Activities

2.3.1 Follow-up the Second Conference on Conservation Biology 5/85 (Unesco, IUCN, FAO, IBPGR).

2.3.2 Based on existing information, formulate guidelines for *in situ* conservation of plant genetic resources.

(1. Food crops (IBPGR)
2. Woody species (FAO)
3. Forage species (IBPGR, FAO)
4. Medicinal plants (WHO)
5. Others, e.g. ethnobotanical species (IUCN))

Goal 3 TO ORGANIZE AND PROVIDE AN INFORMATION SERVICE

Objective 3.1 TO PROMOTE DATABASES ON PROTECTED AREAS AND THE PLANTS THEY CONTAIN

Activities

3.1.1 To develop methodology for establishing model databases in individual protected areas, with application in Biosphere Reserves in China, Mexico, U.S.A (Unesco/IUCN in collaboration with FAO/IBPGR/UNEP).

3.1.2 To prepare a model floristic inventory for a tropical protected area in a region without a Flora (Proposed, Manu NP, Peru; IUCN/Missouri Botanical Garden, with Unesco; funding WWF).

3.1.3 Continued development of IUCN database, especially in the field of Protected Area plant lists. Core funding by IUCN, UNEP, WWF (information from ECG members).

Objective 3.2 TO PROVIDE AN INFORMATION SERVICE ON PLANT GENETIC RESOURCES

Activities

3.2.1 To prepare a model database using the latest GIS/mapping techniques, on the ecogeographical variation for a selected crop (IBPGR, with FAO, IUCN, UNEP/GRID; possibly involving national centres (e.g. botanic garden or university) or IARCs).

3.2.2 To promote a network of sectoral databases on economic plants by scientific institutions (e.g. Kew's SEPASAT) (FAO/IUCN/IBPGR/IARCs).

3.2.3 To prepare a model database on medicinal and aromatic plants. Pilot study on European and Mediterranean regions. IUCN/Reading University, funding by WWF-Italy (feasibility study), EEC, with technical support from FAO, IBPGR, Unesco, UNEP.)

Goal 4 TRAINING IN IN SITU CONSERVATION

Objective 4.1 TO PROVIDE TRAINING OF SPECIALISTS ON IN SITU CONSERVATION OF PLANT GENETIC RESOURCES

Activities

4.1.1 The Working Group to continue to examine training needs for in situ conservation of plant genetic resources (ECG).

4.1.2 To promote the inclusion of in situ conservation in existing curricula in this field (e.g. the Birmingham international M.Sc. course (IBPGR, UNEP, FAO).

Objective 4.2 TO PROVIDE IMMEDIATE SUPPORT FOR FURTHER TRAINING IN PLANT SYSTEMATICS, WITH PARTICULAR REFERENCE TO THE TROPICAL FLORAS

Activities

4.2.1 To prepare a proposal for an immediate expansion in professional training on plant taxonomy (IUCN, with technical support from UNEP, Unesco, FAO, IBPGR).

Objective 4.3 TO UNDERTAKE TRAINING THROUGH FIELD PROJECTS AND PILOT AREAS

Activities

4.3.1 Development of Biosphere Reserves as pilot sites for in situ training and demonstration of conservation linked with development (in Mexico, Kenya, India, China and Cuba (UNEP/Unesco in cooperation with FAO and IBPGR; in progress).

4.3.2 Demonstration and training in pilot sites in Cameroun, Malaysia and Peru (FAO/UNEP in collaboration with Unesco. In progress. Cross ref. Activity 6.1.2

4.3.3 Training component within project on wildlands, protected areas and wildlife management in Latin America (FAO/UNEP).

Goal 5 INTERNATIONAL COOPERATION

Activities

5.1.1 To hold a conference on Botanic Gardens and The World Conservation Strategy (IUCN; in collaboration wih UNEP, FAO, Unesco, WWF, IBPGR).

5.1.2 To promote and facilitate closer collaboration between universities and national institutes on scientific and field surveys (IBPGR, FAO, Unesco, IUCN, UNEP).

5.1.3 To encourage a greater flow of resources into *in situ* conservation of plant genetic resources (FAO, IUCN, UNEP, Unesco, IBPGR).

5.1.4 To develop a projects database for IUCN/WWF field projects and to extend it to cover field projects sponsored and carried out by other ECG members (IUCN, UNEP; first part planned, awaiting funding).

5.1.5 Ensure an appropriate place of *in situ* conservation concerns in national conservation strategies.

5.1.6 Enhance *in situ* conservation through appropriate measures in the implementation of international legal instruments such as the World Heritage and Ramsar conventions.

Goal 6 TO PROMOTE THE APPLICATION OF METHODS OF *IN SITU* CONSERVATION OF PLANT GENETIC RESOURCES

Objective 6.1 IDENTIFICATION, MONITORING AND MANAGEMENT OF POPULATIONS OF SELECTED GENETIC RESOURCES IN EXISTING PROTECTED AREAS

Activities

6.1.1 Genetic resources of woody species of tropical arid zones with particular reference to fuel wood and environmental stabilization (ongoing - FAO - multiple funding FAO/IBPGR/UNEP up to end-1986; FAO 1986, 1987; possible Unesco co-operation).

6.1.2 *In situ* conservation of forest genetic resources for tropical forest ecosystems based on case studies in Malaysia, Peru and Cameroun (ongoing - FAO - funding by UNEP/FAO; possible IUCN and Unesco cooperation).

6.1.3 Assessment and protection of wild mango in designated reserves in Kalimantan (Indonesia), Sarawak and Sabah (Malaysia) - expanding to peninsular Malaysia (ongoing - IUCN/WWF/IBPGR - IBPGR/WWF funded).

6.1.4 Promoting material actions to identify, monitor and manage populations of selected genetic resources in existing protected areas.

Objective 6.2 IDENTIFICATION OF NEEDS AND LOCATIONS FOR *ADDITIONAL* PROTECTED AREAS

Activities

6.2.1 Planning genetic reserves in northwest South America (ongoing - IUCN - WWF funded - possible cooperation FAO, Unesco).

6.2.2 *In situ* conservation of medicinal plants in Sri Lanka (proposed - IUCN in co-operation with Unesco and WHO - WWF funded).

6.2.3 Model conservation and utilization of genetic resources in one or more selected biosphere reserve (proposed - FAO/Unesco in cooperation UNEP, IUCN, IBPGR - multiple funding sources).

6.2.4 To conduct assessment of the adequacy of species and genetic resource conservation in the tropics (IUCN/UNEP).

Contract Paper No. 11

International Laws and Associated Programs for Conservation of Biological Diversity

John Barton - International Technology Development
Barbara Lausche - World Wildlife Fund/Conservation Foundation

December 1985

Office of Technology Assessment
U.S. Congress

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INTERNATIONAL LAWS AND ASSOCIATED PROGRAMS FOR CONSERVATION OF BIOLOGICAL DIVERSITY

JOINT OPTIONS FOR CONGRESS

prepared by:

Barbara Lausche
World Wildlife Fund-US

John Barton
International Technology
Management

prepared for:

Biological Diversity
Assessment
FRR Program
OTA, U.S. Congress

December 1985

December, 1985
Barbara Lausche
John Barton

International In situ/Ex situ Laws and Programs: Options for Congress

This paper is a synthesis of major options for Congress, based on the two papers, "International Laws and Associated Programs for *In-situ* Conservation of Wild Species," by Barbara Lausche and "International Institutional/Legal Frameworks for *Ex situ* Conservation of Genetic Diversity," by John Barton.

Before presenting specific options, two points need review. First, an effective United States national policy for conservation of biological diversity could include two approaches, which Congress may need to emphasize at different times: (1) strengthening existing and encouraging the creation of new international *treaties* and *soft law*, and (2) strengthening and supporting the creation of new domestic and international *institutions*. Each approach has advantages and disadvantages and depends to a certain extent on complementary support from the other. On the one hand, treaties provide a concrete focus for action at the international level, and provide a basis and reinforcement for programs at the national level. At the same time, however, most actual conservation occurs at the national and scientific levels, and the negotiation of treaties (particularly those that may govern the international flow of genetic resources) raises questions of the allocation of economic benefits and costs. Thus, proposals for such treaties may increasingly generate economic and political debate.

Efforts to strengthen existing international institutions, on the other hand, are becoming increasingly critical for the effective enforcement and application of existing international treaties and to the development of stronger treaties. Nevertheless, these institutions are limited in their effectiveness when the underlying law is inadequate.

The second preliminary point concerns the character of coordination between *ex situ* and *in situ* conservation. This coordination includes several tasks that must be taken into account when specific procedures are considered:

1. The allocation of priorities for *ex situ* and *in situ* conservation efforts so that the two types of programs complement each other and conserve as great and as well chosen a variety of species as possible with the limited resources available. This task involves both scientists and donors.
2. Cooperation in scientific research, and particularly in conducting the ecogeographic surveys that can help define needs and priorities for both types of preservation.
3. Integration of *in situ* and *ex situ* conservation in national development planning and project implementation, both to coordinatie priorities and to avoid overlaps and inconsistencies.

Improved *in situ*/*ex situ* coordination at the international level will require working level expert committees dedicated to specific species or groups of species, including those organized along user lines (e.g. medicinal plants), in order to identify the feasibility, needs, and potentials of different conservation methods.

This background should be kept in mind in evaluating the following options:

1. Congress could provide increased long-term support and commitment to existing international laws and associated programs in both the ex situ and the in situ areas. Specific possibilities include:

A. Increased long-term financial, technical, and staff assistance to the Secretariats of the major international conventions and programs in the biological diversity conservation area. Congress might wish to make the allocations itself or might choose a specific executive agency for this purpose. This option could, for example, help expand programs like that of the IBPGR to new kinds of plants. Or it might provide for strengthening of the work of UNEP or non-governmental organizations in encouraging in situ conservation.

B. Assistance to educational programs for training of developing country professionals as well as support for infrastructure needed to implement the programs at national level.

C. Support for information development and scientific exchange on management, inventory, and monitoring techologies useful for field application. The Council of

Europe's biogenetic reserves network is an important source of such information along with United States entities.

D. Direct support for international and non-governmental organizations working to create global networks of conservation areas and entities, e.g. protected areas, biogenetic reserves, and current *ex situ* collections.

2. In light of the need for improved knowledge about the actual benefits and limitations of current international *in situ* and *ex situ* laws and programs for biological resources conservation, Congress could request the executive to conduct or encourage reviews of the scientific and institutional effectiveness of and gaps in existing international activities. A program of monitoring of national and international conservation systems could also be established to improve the flow of information on performance. In some cases, this will require working through international organizations, some of which already have procedures to evaluate the management and technical performance of their programs.

3. In funding and shaping United States domestic biological diversity conservation programs, Congress could reinforce its international activity by requiring that a portion of these domestic programs benefit developing nation biological diversity conservation programs. Thus, Congress might provide support for United States-based education, research, or training, earmarked for developing country problems or students. The United States land grant universities might be encouraged to increase cooperation with foreign or international biological diversity conservation programs. The creation of United States institutions

to coordinate and improve communications among United States *in situ* and *ex situ* programs (e.g. in forestry) could be an important step to provide an example for developing nations and the international community.

4. Congress could emphasize in national policy the need for greater integration of biological diversity conservation with international economic development. For example, it could extend the International Environmental Protection Act of 1983 to reflect the conservation and development linkages defined in the World Conservation Strategy. Design of development projects by bilateral and multilateral development assistance agencies could take more fully into account the existing international conservation obligations of the host country, and the ways that international conservation policies and programs would be furthered by the projects. Congress could direct those development assistance agencies to which it provides funds to increase project level coordination and consultation among donors, international conservation organizations, and non-governmental environmental organizations at the first stages of planning. Conservation guidelines might also be developed for specific types of projects (hydroelectric, roads, agricultural, rural water supply etc.). Such guidelines could cover natural resources data collection, protection, training, monitoring, and management, as well as collection of displaced domesticated plant or animal varieties and avoidance of destruction of critical habitats. (There are bills of this type already before Congress, including, for example, e.g. H.R. 2958 and S. 1747.)

5. Congress could support fundamentally new international conservation programs. Specific activities could include support for:

A. Negotiation of new treaties and protocols:

1. To further strengthen commitments to international programs for conservation of biological diversity, and to expand the global system of reserves, parks, and collections, looking particularly to endangered species and habitats, a direction suggested by the IUCN and the World Resources Institute. The reviews suggested in Point 2, above, would help to define the needs for and elements of such additional programs, which would probably emphasize *in situ* conservation..

2. Depending on an evaluation of the pros and cons, which may argue against action in the area, to clarify the legal terms of exchange for genetic material, including that in *ex situ* collections. A prime example would be a new treaty based on a renegotiated FAO undertaking, that would require a commitment to grant global access to genetic resources (with appropriate exceptions for privately-held material), perhaps in return for a package of long-term financial support or provisions seeking to avoid abuses in the exercise of plant breeders' rights. Parallel agreements might be envisioned in the domestic animal, marine resources, and microbial areas. And both kinds of agreement might define new national obligations to collect and conserve germplasm that is being displaced by new varieties.

3. To help create and maintain Secretariats for new treaties and protocols.

4. To create marine protected areas, on both the international and the regional levels.

5. Depending on an evaluation of the pros and cons, to create a trust fund or other stronger funding basis under a new organizational arrangement, for *in situ* and *ex situ* developing nation and international biological diversity conservation programs.

B. Creation or designation of a Secretariat (possibly based on the ECG group) to work with IBPGR, with the FAO, and with existing *ex situ* organizations to ensure the coordination of *ex situ* and *in situ* conservation of plant genetic resources.

C. Creation of an animal analogue of the IBPGR, based on an appropriate new institutional arrangment, including responsibility for coordination of *ex situ* programs with existing and new *in situ* programs.

D. Creation and coordination of *in situ* and *ex situ* genetic resource data banks.

E. Support of biological diversity conservation activities in addition to *in situ* reserves and *ex situ* repositories. These activities might include:

1. Increased use of legal and planning controls to better integrate conservation goals into land use planning. There are successful and unsuccessful experiences in the United States, Europe, and other regions that deserve to be documented, evaluated, and

publicized. Congress could, for example, direct executive agencies to collect data or support research on innovative land-management practices that facilitate conservation of biological resources, to examine their relevance for further research, and to consider applying these approaches in pilot projects and, where appropriate, in conventional development assistance projects.

2. Legal restrictions on introduction of species (possibly including genetically modified species) that appear likely to have the effect of significantly displacing species that are currently present.

F. Initiation of negotiations, based on the earlier FAO negotiations, to resolve the potential conflicts between quarantine and genetic conservation policies. It may be best to do this separately for plants and animals.

6. Congress could enact specific legislation to:

A. Clarify the United States commitment to the freedom of the export of genetic resources (and possibly to clarify quarantine restrictions on the import of genetic resources).

B. Extend the concept of the Lacey Act, as amended, as, for example, by requiring United States corporations and individuals to comply with international rules for the conservation of germplasm and with foreign rules that are consistent with international standards.

Contract Paper No. 12

Living Collections (Plants and Animals)

Grenville Lucas and S. Oldfield
Kew Gardens

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The role of Zoos, Botanical Gardens and Similar Institutions in the Maintenance of Biological Diversity

G.Ll. Lucas and S. Oldfield

Introduction

Historical Development

Plant Collections

Animal Collections
- i) Jersey Wildlife Preservation Trust
- ii) Otter Trust
- iii) Patuxent Wildlife Research Centre
- iv) Rio de Janeiro Primate Centre
- Invertebrates
- Fish
- Reptiles & Amphibians
- Mammals

Networks and International Co-operation

- i) International Union for Conservation of Nature and Natural Resources (IUCN)
- ii) American Association of Zoological Parks and Aquariums (AAZPA)
- iii) The International Zoo Yearbook (IZY)
- iv) Studbooks
- v) International Species Inventory System (ISIS)
- vi) International Union of Directors of Zoological Gardens (IUDZG)

CONSERVATION RESEARCH in Living Collections

CONSERVATION EDUCATION in Living Collections

LIMITATIONS
- BIOLOGICAL LIMITATIONS
- OPERATIONAL LIMITATIONS

RECOMMENDATIONS

REFERENCES

Appendix 1 SSC Specialist Groups
Appendix 2 IOS Code of Conduct

The role of Zoos, Botanical Gardens and Similar Institutions in the Maintenance of Biological Diversity

G.Ll. Lucas and S. Oldfield

The role of Zoos, Botanical Gardens and Similar Institutions in the Maintenance of Biological Diversity

G.Ll. Lucas and S. Oldfield

INTRODUCTION

In the preparation of this paper the gradation of institutions involved in *ex situ* conservation of genetic resources was found to be infinite with their combined contribution to the maintenance of biological diversity being very valuable. The primary reasons for setting up these institutions were also many and various and accounted for numerous variations in their conservation objectives and capabilities. This paper covers fully commercial self-sustaining enterprises to charitable trusts, government research centres and private collections. They all could play a part in the preservation of biological diversity and although many do, by no means all those do so knowingly.

Biological diversity and its maintenance can be measured in many different ways and at many different levels. For instance the sum total of all taxa held in zoos and botanic gardens is very large in absolute terms but in relation to the number of taxa in the wild this figure is much less impressive. The situation changes when one looks at specific groups of very rare animals and again with a small number of plant species where the populations held in captivity either are or may be one hundred per cent of the total population.

Rarity and the degree of threat to wild populations provide one method of assessing priorities for conservation research projects. Such information also indicates to a zoo or botanic garden that they need to channel more resources into a particular endangered species conservation programme.

Absolute numbers of a species held by a number of zoos and botanic gardens must not be allowed to cloud the issues. Twenty separately held rhinos in twenty zoos have between them a considerable genetic variation - however, if they are not linked into a programme that ensures breeding and thus genetic interchange, this or any other total figure is meaningless as a measure for long term conservation of biological diversity.

Living collections can and do serve a range of functions in relation to conservation of biological diversity. Foose (1983a) most valuably lists six main ways in which zoos can contribute to conservation, ways which stand equally for botanic gardens. They are:

1) by serving as refugia for taxa destined for extinction in the wild.

2) by providing propagules for re-population of natural habitats.

3) by reinforcing natural populations that are so small and fragmented that they are not genetically and demographically viable.

4) by maintaining repositories for germplasm and as an adjunct or an alternative to populations of living animals.

5) by conducting research that will improve management for wild as well as captive populations.

6) by educating the public to support conservation of wildlife in natural habitats.

To spend time discussing the definitions of zoos and botanic gardens or "collection" would be academic at this point, but it is essential to understand that whatever type of institution is involved it needs for conservation purposes, appropriate scientific backup. All too many "zoos" and "botanic gardens" have the name but offer nothing further to the preservation of biological diversity.

The particular skills of the staff of "good" zoos and botanic gardens, which are used to develop and maintain captive collections are becoming ever more needed and employed in the management of wild populations and habitats. It is a sad reality that eventually all the wild areas of the world will be "managed", and increasingly the skills of the zoo and botanic gardens will be needed to ensure the very biological diversity we often unthinkingly accept today. Intensive reserve management and recreated habitats will be ever growing elements of general land management, and here again the practical skills some of which are already available in zoos and botanic gardens will need to be adapted so that they may be applied in "wild" situations.

Frankel & Soulé (1981) point out the fundamental limitation on living collections is that they provide for the maintenance of individuals or groups but not for their evolutionary change. They thus state that 'zoos and gardens may preserve but only nature reserves can conserve'. This essential point must be noted and be taken into account when developing breeding and cultivation programmes. However, for our purposes we feel the dividing line between the wild and 'non-wild' is becoming increasingly blurred and it is not helpful to be too limited in our consideration. It is of course essential to maintain as many tracts of lands undisturbed as possible as protected areas, but it seems likely that these will become increasingly managed, and dependent on exchange with other living collections whether captive or "wild". The creation and utilisation of reserves should be an element in present and future planning for institutions with living collections.

A fundamental factor in the consideration of living collections in the area of maintaining biological diversity is the time scale - short term success is of practically no value - very long term cultivation and "captive" maintenance through successive generations are essential not at the "specimen" level but at the species population level if this is to be considered successful. The time scale can therefore be in months between generations of species of smaller fauna to many hundreds of years for some woody plant species.

At present many living collections are still too dependent on specimens taken directly from the wild. Although limited collection may be entirely valid and indeed essential for scientific and conservation reasons, wild specimens are still acquired all too often because no alternatives are readily available, to satisfy the criteria of dealers and consumers alike, or through a lingering preference for plants (or animals) of wild origin. Even when wild specimens are necessary for breeding purposes, for animals at least, their origin has often been inadequately documented. Conway (1980) has pointed out that, 'Obtaining wild animals for captive herds and flocks has usually been a fortuitous (if not random) process. Zoos and researchers have felt lucky to have even a rough idea of their animals' provenance when they obtained them from dealers'. Cherfas (1984) estimates that 35 per cent of zoo animals registered at the end of 1983 were not born in captivity. Half of these were definitely brought in from the wild, representing over 10,000 creatures. As regards plants, a limited amount of material in the form of seeds or cuttings can be collected from the wild without damaging these populations giving a distinct advantage to botanic gardens. Although still, too often, the avid collector or for the commercial grower, or even the botanic garden can ruthlessly decimate a limited or fragile plant population.

Reliance of living collections on the input of wild specimens will hopefully decline as techniques of breeding and propagation are increasingly researched, improved and practised. Progress, in terms of clearer understanding of the genetic principles of maintaining rare species in captivity, the role of botanic gardens in conservation and international co-operation generally, have been particularly rapid in the past ten years. Potential for the future is limited primarily by a lack of perception by the public and politicians of global conservation needs, and the very major problems posed by limited funding, although the material represented in the collections is without doubt vital to the quality of life, to put it at its most emotional level, as well as being essential for future potential economic resources at the practical level.

The current status of zoos and botanic gardens, their various roles and contribution to conservation depends in part on their historical development which is outlined in the next section.

Private collections, ranging from the amateur specialist in a single taxa to the multi species private zoo do have a major role to play in the maintenance of biological diversity. The money available whether from individual enthusiasts or their societies, appears to be far in excess of that spent collectively by zoos and botanic gardens, although it must be recognised that the majority of private collections are not maintained solely for conservation aims but to fulfil many other interests too.

Specialist plant or animal societies are increasingly taking conservation into their aims and objectives, and more importantly their general thinking, and in doing so are becoming an important element in maintaining biological diversity. Equally, however, there are individuals within the societies, along with other collectors, who represent a continuing threat to wild species. They simply want to own specimens and are motivated by the "stamp-collecting" instinct. Unfortunately and sadly, not only in the past, status has been attached to owning rare species. National and International legislation is in force in many countries to prevent over-collecting of species from the wild, in many cases however it is quite inadequately enforced and probably unenforceable as a result of a lack of appropriate effective infrastructure.

The sheer enthusiasm of the "amateur", the care and attention given, and the exceedingly wide depth of knowledge acquired and applied to species is a significant factor in the maintenance of biological diversity. It does not, however, reach anything like its full potential because of a lack of organisation - often impossible to establish - as it is the go-it-alone ingredient which so often accompanies success. Ways must be found to draw these enthusiasts or their skills into the invisible, if not visible, network in order to maximise their contribution to the maintenance of biological diversity by ex situ methods.

HISTORICAL DEVELOPMENT

The beginnings of botanic gardens and early animal collections (zoo precursors) are shrouded in the veils of history. Man has apparently kept pets from his earliest beginnings and this appears to have expanded into larger collections of animals with the change from a nomadic to a settled way of life. There are examples of menageries in Ancient Egypt, Rome and China, with animals kept for their curiosity value, for religious reasons and for live entertainment.

Alongside the hunter-gatherer way of life, with collected species used solely and directly for survival, man came to collect plants and animals for aesthetic and cultural reasons. The range of plants collected included the purely functional food species, medicinal and 'magic' plants and decorative species, all of which were eventually brought together and grown in 'gardens'.

There is a much sharper line drawn between the domestic animals, the pet species and those which one considers to be zoo species. It is true to say, however, that almost any species in a zoo has been someone's pet, somewhere at some time. Botanic gardens with the wide range of food, spice, medicinal and magic plants had various levels of utility whereas zoological gardens were mainly developed for whim or pleasure.

For whatever reasons the collections were created, inevitably curiosity led to the development of natural history studies and the many sciences which stemmed from it. At the simplest and most fundamental level living collections led to an interest in identifying, classifying and obtaining a large range of species within a group.

The essential elements in this paper relate to the diversity of species held in living collections and the intra-specific variation within them. In the development of living collections the 'stamp-collecting' mentality has usually prevailed, i.e. the collection of as wide a range of taxa as possible, with a very limited number of individuals of each. This situation is now generally changing. The holdings of Frankfurt Zoo show for example how there has been a trend towards fewer species and more individuals of each. In 1862, 1190 animals of 362 species were kept on the Zoo's four hectares. In the present Zoo (eleven hectares) there were 1638 animals in 1981, from 323 species (Dmoch, undated). Breeding within living collections has led to two trends; the encouragement and development of unusual varieties and forms such as albino types and the opposite trend towards inbreeding to produce uniform and standard progeny, both of which by definition are a threat to biological diversity.

As one might expect various types of botanic gardens can be recognised based on their historical background. The first kind is the moribund garden, historically important but now underutilised and understaffed. Such gardens are often attached to universities and were originally used as teaching aids for apothecaries and doctors. Their medical and biological resources have generally been overtaken by the changing needs of modern science but some scientifically interesting early cultivars remain within these collections.

The next category are the municipal botanic gardens developed almost as status symbols in the Victorian age. Many have disappeared but some remain as 'parks'. In the same era colonial botanic gardens (British, French, Germany, Spanish and Portuguese) were developed as stations for the transfer of germplasm around the Tropics. Sadly many of these gardens are now also moribund, or again maintained as open parks.

Other long-established gardens particularly in the Old World have had a more controlled and maintained development, either deliberately being maintained as historical monuments or adapting to modern needs along with the development of the appropriate natural sciences. Many such gardens are now in a stage of transition as the teaching of traditional botany with its emphasis on systematics declines but the importance of ex situ conservation is not fully recognised. In the New World more recently created botanic gardens are often more active and commercially-minded (they need to be self-sustaining) developing many specialist gardens within the garden - "Japanese", "Rose", "Herbal", "Scented", etc. being designed especially to attract the tourist and neighbourhood visitor. The scientific input and output remains a very variable factor - but the 'conservation of nature' and horticulturally important species is becoming a growing element in their thinking and planning.

PLANT COLLECTIONS

Frankel (1976), pointed out that the conservation efforts of botanic gardens are concerned with wild plant species, irrespective of whether or not they are useful to man, whereas the Food and Agriculture Organisation (FAO) and other organisations are concerned with narrowly defined economically important cultivars and their wild relatives. In relation to tree species Richardson (1970) states that, 'traditional arboreta have particular relevance for conservation of species in which the gene pool is small and under pressure of destruction, and for individuals having distinctive characteristics which are at present of no apparent economic significance'.

The general public's view of botanic gardens and arboreta as living museums reflects their traditional roles as collections of individual specimens, 'for limited scientific purposes, or for educational and recreational use'. (Richardson, 1970). Walters points out however that botanic gardens, together with zoos have acted as 'refuges' since the late 19th Century and it is simply a more formal and explicit commitment to conservation that is required.

A general perception of the need to conserve plant diversity both in the wild and in living collections is relatively recent and has only become part of mainstream conservation thinking in the past fifteen years. The progress in that time span has been good. The awareness initially developed in a few scattered gardens but it was focused by the activities of the Threatened Plants Committee (TPC) set up in 1974, based at the Royal Botanic Gardens at Kew. The initial activities of TPC were to develop lists of threatened species world-wide using the existing networks of botanists. Early on in the work it became obvious that the botanic gardens' horticultural expertise had a role to play in conservation activities, and so Kew hosted two conferences to discuss these activities.

The first conference held in 1975, covered the principles and methods of ex situ plant conservation, including techniques of collecting, cultivation, documentation and also aspects of education, legislation and co-operation at an international level. The proceedings are published in a book entitled "Conservation of Threatened Plants" (Simmons et al., 1976).

The second conference was held in 1978 and the proceedings are recorded in "Survival or Extinction" (Synge and Townsend, 1979). A similar range of topics was discussed with rather more emphasis on the need for national policies and activities. In addition the second conference called for the development of an international network of botanic gardens to be established to co-ordinate on conservation work. In response to this IUCN's Species Survival Commission (SSC) set up the Botanic Gardens Conservation Co-ordinating Body (BGCCB)in 1979. This is now run by the IUCN's Conservation Monitoring Centre which incorporates the Threatened Plants Unit (TPU), formerly the TPC Secretariat).

More details of the work of the BGCCB are given in section on networks. It is important to mention "the Body" at an early stage in the discussion of ex situ plant conservation as it has played such an integral role in international action. It should not be forgotten however that living collections, both botanic gardens, commercial institutes and private plant collections, have for years been growing and propagating plants which are rare in the wild. In many cases such activities were carried out without realisation of the conservation status of the plants and one of the strengths of BGCCB has been to channel CMC's data on rare and threatened species to botanic gardens.

It is only over the last ten years that information on the conservation status of plants in the wild has become generally available. The Conservation Monitoring Centre (CMC) acts as a clearing house for lists of threatened plants developed nationally or initiated internally where resources were unavailable locally. One of the first national lists produced was that for the US prepared by the Smithsonian Institution in response to the Endangered Species Act 1973. For the plant world the collection of data on rare and threatened species, the development of conservation legislation and developing role of botanic gardens in conservation have proceeded rapidly in a relatively short space of time.

There is however still very much to be done. Taking one example alone the Smithsonian list of threatened plants of the US has not yet been circulated through the BGCCB or the American Association of Botanical Gardens and Arboreta (AABGA). It has been estimated however than only 4 per cent of the endangered plants native to the US are presently conserved in any botanical garden or arboretum (Ayensu & DeFillips, 1978). The newly formed Center for Plant Conservation as discussed below will hopefully remedy this situation. A list of Hawaian threatened plants has been circulated to members of BGCCB and a report published of their holdings.

IUCN has so far located 3948 threatened plant species in cultivation by members of the BGCCB which is more than one-quarter of the known threatened plants in the CMC computerised data base. (Walters & Birks, 1984). The figure includes Angiosperms, Gymnosperms and ferns and is obviously a tiny proportion of the total range of threatened plant species. It also represents a tiny proportion of the total biological diversity currently maintained by botanic gardens. There is clearly a need to put more emphasis on the cultivation of rare and threatened species by botanic gardens.

Considering the total number of threatened plants (estimates vary from 25-40,000 for flowering plants alone), it is obviously unrealistic to think in terms of botanic gardens taking responsibility for all species. There may however be value in botanic gardens selecting a particular endangered species as its symbol. It would certainly be desirable for botanic gardens to specialise in the cultivation of particular groups of threatened plants. Ideally this should relate to the local flora which would ensure that climatic factors do not add to the artificial selective pressures on the plants in cultivation. Unfortunately the imbalance in the number of botanic gardens in the developed world and concentration of botanical expertise in those countries, however, means that many threatened tropical plants must be cultivated under glass house conditions for the foreseeable future.

Examples of botanic gardens concentrating on the cultivation of locally threatened species are given in 'Survival and Extinction' (Synge & Townsend, 1979). These range from the conservation of plants threatened in Eastern England (Walters, 1979), to the conservation of the highly endemic and threatened plants of South Africa (Hall & Rycroft, 1979) and the Canary Islands (Bramwell, 1979).

Planning of conservation collections on a geographical basis can be taken one step further by regional co-operation between botanic gardens, ensuring both unnecessary duplication of holdings and also adequate representation of endangered species in cultivation.

In the U.S. the Center for Plant Conservation plans to co-ordinate such activities. This new center developed at the Arnold Arboretum of Harvard University and the New England Wild Flower Society is based at the Arnold Arboretum.

The primary goals of the Center are:

1) Establishment of a national network of gardens and arboreta committed to the protection of endangered species;

2) Creation of an endangered species data bank to collection, catalogue and share basic information about critically threatened plants.

3) Development of live plant collections by selected Regional Programmes, including propagation and storage facilities, and

4) Support of research and education activities regarding the biology and conservation of endangered species.

(Thibodeau et al., undated).

Certain living plant collections concentrate on particular taxonomic groups of plants. Such collections relate particularly to groups where there has been intense horticultural interest, such as the palms, cycads, orchids, bromeliads and succulents. Such collections are very important as reference collections and their conservation significance is now more fully recognised. The International Organisation for Succulent Plant Study (OIS) recognises six reserve collections, for example, which are important both in research and in conservation. The IOS has also been a leader in developing a code of conduct which has recently been revised and is included as a annex to this paper.

The main drawbacks to specialist collections of this nature are that the likelihood of hybridisation is increased and also that they are likely to be dependent on personal commitment from members of staff. Also they parallel the public interest of 'megavertebrates' and tend to detract from other less spectacular or attractive groups of plants for conservation resources. BGCCB surveys show how well represented groups such as Mexican endemic cacti, cycads and Madagascan succulents are in cultivation when compared with some of the regional floras such as that of Juan Fernandez.

The planning of conservation collections by collaborating botanic gardens is encouraged by the BGCCB by drawing attention to rare and threatened species which are poorly represented or not in cultivation at all. This is done through the provision of reports and also an annual computer print-out for each member garden detailing those conservation plants notified to IUCN by the garden. The print-outs provide an analysis of the garden's reported holdings in relation to other gardens, i.e. species in five or less gardens are indicated as are species held by no other gardens. Member gardens are encouraged to propagate and distribute species which are represented, especially if these are Endangered or Extinct in the wild.

A further consideration which should perhaps be taken into account in planning ex situ conservation of plants is the nature of the 'rarity' of species. Frankel & Soulé (1981) for example consider 'old rare' and 'new rare' plant species and consider ex situ conservation as being more suitable for the former. 'Old rare' species are those which show extreme specialisation to restricted ecological niches. 'New rare' species are those which have become rare or endangered, 'because of the wholesale alienation of habitats occupied by ecosystems to which they belong'. Protection in situ is considered more appropriate for such species.

For practical purposes an important consideration in management of collections is the suitability of species for the amount of space available. Tree species obviously require considerably more space than species with other life forms. Frankel (1970) has pointed out the suitability of trees in conservation collections in that, 'wide spacing reduces competition, cultivation and pest control are common practice, and a long life reduces the changes of biological erosions resulting from rapid turnover of generations'. However expense and space are clearly restrictions on the maintenance of tree species.

The acquisition of threatened plant specimens cannot in itself be considered the conservation of biological diversity, even when plants are acquired in 'rescue operations'. Propagation must be ensured and management of the population in cultivation carried out based on a knowledge of the breeding system.

Frankel (1970) stated that, 'there is no practicable way in which plant material can be maintained with complete genetic integrity. Hybridisation, mutation and natural selection, changes in the environment and human error, all contribute to erosion of integrity; even seed is not immune from genetic change'. Esser (1976) points out that 'The aim of maintaining collections can only be to preserve as much as possible of the genotypes of the plants as they were taken from nature'. Clearly if there is an intention to ultimately re-introduce a species to localities in the wild it is essential that intra-specific variability is maintained.

Esser (1976) discusses the advantages and disadvantages of vegetative and sexual propagation of plants in living collections. Maintaining plants by vegetative propagation ensures that the original genotypes are preserved as far as possible but in the long term the expression of natural variability is lost. Theoretically of course a clonal population can be established from one specimen of any plant species using vegetative propagation. The cycad, Encephalartos woodii, provides an example of a species which was known only from one plant in the wild. It is now extinct in the wild but reasonably secure in botanic gardens. Aside from such extreme situations, vegetative propagation is usually used to maintain strain collections of lower organisms and is commonly applied to trees, shrubs and perennial plants.

Propagation by seed (sexual propagation) is the usual means of maintaining annual plants and ensures a high degree of variability. The degree of genetic variability is determined by the breeding system. Monoecism, i.e. male and female sex organs on one plant, is predominant in higher plants, whereas dioecism is found in only 10 per cent of genera. Monoecism favours inbreeding but is compensated by factors of homogenic incompatibility, i.e. inhibition of fertilisation of genetically like gametes (Esser, 1976). A knowledge of such factors is important in ensuring viable seed for conservation purposes and ensuring biological diversity.

Techniques of artificial propagation are well-established for plants generally but there is a paucity of research aimed at naturally rare species. Research on propagation techniques tends to be concentrated in the commercial sector of horticulture on those plants with commercial potential. Information is published in the combined Proceeds of the International Plant Propagators' Society which may not be available in the smaller botanic gardens. There has been very little published information on the propagation of threatened species although Wochok (1981) discusses the role of tissue culture in relation to threatened and endangered species.

Tissue culture techniques for rare species are being investigated at botanic gardens such as the Royal Botanic Gardens, Kew. A variety of species have been propagated in the Micropropagation Unit including Macaronesian species made available to members of BGCCB in 1983 (Woods & Miller, 1983).

It is possible that techniques developed in botanic gardens may have applications in commercial horticulture. This is the case with work on the in vitro germination of terrestrial orchids carried out in the Micropropagation Unit at Kew. It seems desirable to maintain and strengthen links between botanic gardens and commercial nurseries which propagate rare plants. The application of research carried out in botanic gardens may for example help to take the presure off wild populations of rare plants which are still exploited commercially for horticulture. The International Plant Propagators' Society with its regional sections seems the most suitable forum for expanding co-operation between botanic gardens and commercial ventures in the field of propagation of rare horticultural plants.

Similarly links between botanic gardens and agricultural and forestry institutes should be encouraged and fostered. At an international level this is undertaken by the IBPGR with its activities concentrated on the conservation of genetic resources mainly in the form of seed. Nationally and locally there could be schemes to conserve locally threatened plants ex situ through the propagation and controlled utilisation of rare and threatened timber and food species. The same applies also to medicinal plants which have traditionally been grown for use by botanic gardens. Cultivation in orchard, field or semi wild situations need the skills of the horticulturist to expand the breadth of what can be grown.

The development of forest tree breeding programmes has brought with it an awareness of the need to conserve genetic variability of timber species. Traditional arboreta, plantations, provenance collections and clone archives have all been considered for the ex situ maintenance of timber species. The drawbacks of traditional arboreta include lack of knowledge of the provenance of many of the specimens they hold, limited sampling from the wild, hybridisation and reduced vigour resulting from self-pollination of isolated individuals of the same species (Bouvarel, 1970) - factors which can be planned for today. Artificial plantations provide space for larger populations but share disadvantages resulting from limited and poorly documented sampling and the risk of hybridisation if not planned adequately. Provenance collections and clone archives have a limited value in the conservation of gene pools, as discussed by Richardson (1970). It would seem that integrated schemes are required to maximise the potential of the various types of tree collections in ex situ conservation. It should be emphasised however that foresters are likely to be interested in a limited number of species and the conservation of intra-specific genetic variation of economically proven species is likely to be their motivation in biological diversity conservation.

Another form of inter-institutional co-operation in plant conservation which is developing and should be fostered further is that between botanic gardens and zoos. A survey of 271 zoos carried out by the authors in 1984 revealed a strong interest in developing plant conservation activities. The American Association of Zoo Horticulture, established in 1983, is a leader in this field, and includes 'to promote conservation programs', in its objectives.

Ex situ programmes for the conservation of species should relate to the conservation of that species in the wild wherever possible. There are few examples of plant species being successfully re-introduced into their native habitat but recent work on St. Helena shows what can be achieved. Financial support from the UK Overseas Development Administration and WWF (UK) allowed a horticulturist from the Royal Botanic Gardens, Kew to visit St. Helena with a botanist funded by the Fauna and Flora Preservation Society in 1983. The main aims of the visit were to set up a propagation unit to save at least some of the island's Endangered endemic plant species, to study sites for their in situ conservation and to increase awareness of the endemic plants. Resulting from the visit twelve of St. Helena's Endangered species are now in cultivation at Kew and propagated material has been distributed to other gardens.

A log of cultural information is being prepared on the St. Helenian plants cultivated at Kew. The methods followed and observations and problems met with are recorded so that the information can be used in similar programmes elsewhere. One of the Endangered species, the St. Helenian Olive (Nesiota elliptica) has been re-introduced to the wild, and replanting with endemics is now part of St. Helena's official forestry policy. A commercial nursery has been established on the island, using equipment bought by a WWF-UK grant to carry out large-scale propagations of endemics. In addition appropriate horticultural measures have been taken to manage the best remaining area of natural vegetation, encouraging endemic species to prosper.

The success of a conservation project of this nature depends to a large extent on the skills and enthusiasm of personnel employed by botanic gardens and their counterparts in the field. Generally the best conservation results obtained by both zoos and botanic gardens are not just institutional successes by the establishment providing the right resources such as equipment and finance. They very much rely on the skills and dedication of employees in an exact parallel to the dedicated "amateur" of many single individual private collections. The encouragement, development and support of enthusiastic staff is an essential element in a successful zoo or botanic garden role.

Another form of involvement by botanic gardens in conservation of natural habitats is through the management of nature reserves or other 'wild' areas. This seems to the authors to offer the most encouraging prospect for long term biological diversity conservation. Cultivation based on careful field observation, aids the re-stocking of the habitat. The 'natural' source of propagules would provide for propagation to be carried out locally with the added possibility of excess material being sold as plants with documented provenance so beloved of many horticulturists and collectors.

ANIMAL COLLECTIONS

Examples of Endangered animal species that have been successfully bred in captivity and returned to the wild are well-known. The American and European bison, Przelwaski horse, Arabian Oryx, pink pigeon and Ne-Ne immediateley spring to mind. Breeding populations of other rare and threatened animals are established but on the whole the number of species regularly breeding in captivity is still relatively small. Conway (1980) points out that, 'nearly one-twelfth of all the species of birds and one-sixth of the mammals have been bred in zoos in two years'. It is widely assumed in the zoo world that progress in captive breeding of endangered species will accelerate in the future and trends since 1980 appear to confirm this.

Zoos have concentrated their efforts in breeding rare species of birds and mammals. This reflects the disproportionately large share of conservation resources applied to these groups generally as a result of greater public interest and concern. As mainly commercial self supporting institutions, zoos of course need to be aware of the demands of the public, considering what type of animals they prefer to see, and the publicity value of baby mammals. In terms of managing biological diversity, however, zoos are currently taking responsibility for only a few representatives of a limited taxonomic range.

In general zoos have a variety of roles to perform including education, entertainment and research along with species conservation. Some zoos do however concentrate primarily on conservation and perhaps the most famous is that run by the Jersey Wildlife Preservation Trust, (JWPT). Other centres concentrating solely on conservation include those devoted to a single group such as the Otter Trust in the U.K., the Rio Janeiro de Primate Center in Brazil, or on the animals of a particular region such as the Patuxent Center. These four examples show what can be achieved in ex situ species conservation.

In addition other major multi-purpose zoos do of course carry out effective conservation programmes. Notable achievers include the New York Zoological Society (NYZS)and Frankfurt Zoo, F.R. Germany which fund active overseas in situ conservation programmes together with their ex situ conservation activities. The Zoological Society of London with the first truly "scientific" zoo to be established continues to play a leading role in research and the NZP, Washington is another leader in the field.

We now include some examples of different approaches which we feel lead the way - there are many others but for their brevity they serve well.

i) Jersey Wildlife Preservation Trust (JWPT)

JWPT was inaugurated in 1963 and is devoted entirely to the concept of captive breeding of endangered species. The objectives of JWPT are:

i) To build up under controlled conditions breeding colonies of various species of animals threatened with extinction in the wild state.

ii) To organise special expeditions to rescue seriously threatened species.

iii) By studying the biology of those species, to amass and correlate data which would help towards protecting those endangered animals in the wild state.

The work of the trust is based at the Jersey Zoo which was founded in 1959 and now provides an excellent model of ex situ animal conservation. Funding of the Trust's activities is mainly derived from income from admission charges and annual subscriptions paid by its membership.

The work of JWPT is international in scope with endangered species programmes agreed with relevant governments wherever possible. The ownership of the parent species and a large proportion of the offspring remain the property of the co-operating government. Conservation activities relating to the Mascarene fauna have for instance, been one of the integrated programmes carried out by the Trust.

In 1980, Durrell & Durrell reported the progress of the Trust in breeding six species of the Mascarene fauna providing the most extensive ex situ collection of the island's wildlife. Animals forming the breeding nuclei were loaned to the Trust by the Mauritian Government following a visit to the island in 1976. Co-operation with the Government has included the training by JWPT of a conservation officer based now at Black River Aviaries, Mauritius. On Mauritius itself captive breeding programmes sponsored by WWF, ICBP and the Government have involved four species.

Research and education are two important components of the work of JWPT. In its simplest form the research involves the accumulation and analysis of information based on the various animals maintained in captivity. This includes, for example details of their behaviour, reproduction and development, nutrition, pathology and records of general husbandry techniques. Such information is invaluable particularly as it often relates to species not held elsewhere in captivity and data which could not be easily collected in the wild. In addition field research is carried out by members of the staff. Research papers are published in Dodo, the journal of the Trust.

Education takes on two main forms at Jersey Zoo. The Education Department provides classroom facilities, an Education Officer, and audio-visual aids, for schoolchildren, Trust members and university students. However equally and perhaps even more importantly training on aspects of captive breeding are provided by JWPT to foreign students providing them with the expertise to use in their own countries. The International Training Centre provides various courses normally lasting up to 16 weeks and includes an annual three-week summer school, dealing with specific topics.

ii) Otter Trust

The Otter Trust was set up in 1972, with its headquarters in Earsham, Suffolk, U.K. As well as being successful in captive breeding the Otter Trust has pioneered the idea of 'otter havens'. These are carefully controlled stretches of river, maintained and monitored for the protection of wild otters. The full co-operation of the owners is of fundamental importance in the conservation programme and is sought at an early stage (Wayre, P. 1979).

One of the long-term intentions of the Otter Trust since its establishment has been to restore the European otter (Lutra lutra) to suitable wild habitat. In the UK the otter population in south-eastern England has become particularly fragmented. In some instances the population had become too small to be viable and capable of expanding into existing gaps. Re-stocking is obviously therefore an important conservation option in this area.

In 1983 the stock of breeding otters at Earsham was considered large enough to warrant the return of young animals to the wild. Re-introduction of captive bred stock is now underway and eight animals had been released by September 1984 (Wayre, P. 1985).

A further aspect of the Otter Trust is its work in education. Concentrating on one of the UK's most endangered and appealing mammal species no doubt helps to promote interest in conservation. The very success of the Otter Trust has been its specialisation, with an emphasis on a local species. An integrated programme of in situ and ex situ conservation for the European otter, with the full involvement of sympathetic landowners and the Nature Conservancy Council (UK Governmental Conservation Agency) shows what can be achieved on a local scale.

iii) The Patuxent Wildlife Research Center

The Patuxent Center provides an example of what can be achieved at a national level by a government-maintained research institute concentrating on the scientific study and propagation of threatened wildlife. Erickson (1980) provides an account of the Center and the following summary is based on his paper.

The Patuxent Center's two main aims are:

1) to obtain information on the numerical status, distribution, behaviour, ecology, physiology, and genetics of endangered species in the wild and
2) to maintain confined populations of these species for scientific study and the production of stock for bolstering wild populations.

Since its establishment in 1965 staff have worked on a range of over 60 U.S. threatened species of reptiles, birds and mammals. Often substitute or surrogate species are used for research. The conservation programmes are carried out in conjunction with field stations in six states and Puerto Rico, where animals can be studied in their natural environment.

The Patuxent Center has been successful in breeding threatened species in captivity and re-introducing them to the wild. Taking one example alone, that of the masked bobwhite, restocking with captive bred birds has taken place in Arizona and also in Sonora, Mexico (Erickson, 1980).

The masked bobwhite, a subspecies of the bobwhite quail, occurred naturally in southern Arizona until about 1900. It remained in limited numbers in Sonora where vegetation was not so affected by drought and overgrazing. Fifty seven wild birds from Mexico captured in 1968 and 1970 formed the breeding stock at Patuxent. Substantial numbers of re-introduced quail are now surviving and reproducing in the wild, and have spread to other suitable habitats.

The land into which the captive-bred quails have been released is leased under a co-operative agreement involving the Victorio Land and Cattle Company, Arizona Game and Fish Deartment and the US Fish and Wildlife Service. The land is managed, with livestock grazing reduced to allow the development of denser vegetation which serves to protect the Masked bobwhite from its natural predators.

The strength of the Patuxent Center lies in its integration into a legally defined national conservation programme for declining species. Studying species both in the wild and in captivity allows in depth conservation information to be recorded. This dual approach is in fact essential if animals are to be truly conserved and it is a factor shared by all the four examples of living collections described here.

iv) The Rio de Janeiro Primate Center (CPRJ)

This Center was established in 1979 specifically for the breeding of threatened South American primates. Wolters (in press) describes how it now maintains a sizeable proportion of the gene pool of both the golden Lion tamarin (Leontopithecus rosalia) and the white-faced marmoset. The Center also houses successful breeding colonies of almost the entire captive populations of Callitrichids. In 1983, 120 specimens of Callitrichidae belonging to different species were represented, including over 20 individuals of each of the three lion tamarin species (Mallinson, 1984). The formation of similar groups of threatened cebid species which live in S.E. Brazilian rain forests is currently being established.

The golden lion tamarin has been bred so successfully in captivity that its re-introduction to the wild is now being carried out. This is part of a carefully co-ordinated international conservation programme.

"Commercial" establishments involved in the propagation of rare and threatened animals for trade also play a role in the maintenance of biological diversity. Such operations can contribute to species conservation either directly by breeding threatened species or indirectly by reducing trade pressures on wild populations or through carrying out research.

The IUCN Wildlife Trade Monitoring Unit has carried out a survey of wildlife farming operations involving wild mammals, birds, reptiles and amphibians, including both common and uncommon species. A directory of such operations is maintained by WTMU. Obviously the quality of the various schemes varies considerably along with their contribution to conservation. This is an area where considerable research is needed to identify the successful i.e. productive and "non-threatening" operations as distinguished from those which pose a threat to wild populations and remain therefore a threat to biological diversity. Subject to careful monitoring commercial breeding centres should not be overlooked in conservation planning and should be encouraged where appropriate.

The need to include other types of institutions in captive breeding of threatened species has been recognised by Wolters (in press). He considers the role of private collections, and mentions the World Pheasant Association as a good example of collaboration between zoos and private collections. Wolters however concludes that, "Different types of establishment still show a marked lack of readiness to co-operate with each other. This is often purely and simply a matter of commercial protection of "their product" and perhaps mechanisms to protect capital investments can be found.

Consideration in ex situ animal conservation has so far mainly been given to the larger creatures, the obvious "zoo candidates". The majority of animal species do not fall into this category, but need also to be considered in planning for the ex situ conservation of biological diversity.

Invertebrates

Discussions on ex situ conservation of animal species have scarcely considered invertebrates, although invertebrates of many species have long been kept and bred in captivity. For some species this has been for economic reasons, for example the silk worm (Bombyx mori), whereas others have been kept for education research or as pets. These commercial operations have grown in diversity over the years and whilst outside the terms of reference of this paper must not be ignored for the role they play in maintaining the biological diversity of some species. Shell fish industries have for example selectively maintained a range species.

Captive breeding of Lepidoptera has become well-established far beyond the silk worm industry and is now seen as an important method of butterfly and moth conservation. Such captive breeding is usually outside the orbit of the traditional zoos, concentrated as it is in the specialist and fully commercialised sector. Recent interest in breeding butterflies has been promoted by the use of artificial diets which allow cost-effective production of large populations of butterflies and moths, even when their natural food plant is unavailable (Morton, 1983).

"Farming" of butterflies tends to concentrate on the production of dead specimens for the souvenir and decorative trade and on living specimens for display purposes. The former tends to be concentrated in developing countries and is seen as a valuable means of providing income and employment, whilst at the same time removing trade pressures on wild populations. Hutton (1985) discusses the success of butterfly farming in Papua New Guinea (where the industry is most highly developed) which has extended to include other insects, particularly beetles. Hutton also points out that the publication of a booklet on the PNG programme has 'elicited a great deal of interest and enquiries from other countries including Indonesia, the Solomon Islands, India and some South American countries.'

Butterfly rearing in Papua New Guinea is a form of farming or ranching rather than captive breeding as such, as the methods used serve to enhance production of specimens in their natural habitat. The techniques developed, however, have a bearing on ex situ conservation. It would seem important to establish ex situ breeding colonies of endangered species as a safeguard against the possible collapse of a commercial interest which is at present still developing.

One of the few examples of invertebrates being maintained in a living collection solely for conservation reasons is provided by the propagation of Moorea Island snails at Jersey Zoo. JWPT currently holds breeding populations of five species and subspecies of the genus Partula, all of which are endemic to Moorea Island and critically Endangered in the wild (Bloxam & Tonge, in press).

Fish

The captive breeding of fish again is a feasible option and is well known for certain fresh and sea water species as a commercial venture. Maitland and Evans (in press) point out that recent developments in controlled mass rearing techniques and modern methods of artificial propagation, including the use of hormones and in vitro fertilisation could be applied to rare and threatened species. In the conservation of rare and threatened fish however, captive breeding has been used only in a very limited way.

A CMC survey carried out in 1981 to identify which of the 217 species included in the 1979 IUCN Fish Red Data Book were held and bred by public aquaria, revealed only 23 species of conservation interest in captivity. Records in IZY for 1980, 1981 and 1982 do not show an increase in this number

(Maitland and Evans, in press). Some of the 23 species are threatened in the wild but are widely bred for the aquarium trade with examples including Barbus tileya (Cherry barb) and Belontia signata (Comb Tail) from Sri Lanka and Cynolebias constancae from Brazil.

Zoos and aquaria are as yet doing little to display fish of conservation concern and, in fact, the vast majority of animals on show in aquariums were captured in the wild (Cherfas, 1984). Private aquaria do have a role in conservation even if again this has so far been limited in practice. Members of the Society for the International Conservation of live bearing fish (members in the U.K., F.R.G., Austria and U.S.) are actively breeding threatened species as are several other societies.

Perhaps the best example of what can be achieved by ex situ fish conservation is provided by the National Fish Hatchery, Dexter, New Mexico, run by the U.S. Fish & Wildlife Service. This hatchery is concerned with native desert fish species which are under threat in the wild. Since its establishment in 1974, 20 different species have been maintained. The successes of this hatchery are further reviewed by Maitland and Evans (in press).

Reptiles and Amphibians

The captive breeding of certain reptiles and amphibia is well established particularly in the commercial sector. The past two decades had seen notable successes in the breeding of crocodilians, for example, following the breeding of both the American alligator (Alligator mississippiensis) and the Indian mugger (Crocodylus palustris) in captivity in 1960 (Bustard, 1980). The crocodilians are in fact a good example of a group where specialist breeding programmes in association with for example, National Parks can provide a "captive breeding" population of sufficient size and diversity to ensure the maintenance of the species in the wild and yet use all the techniques of the zoo world - something which is likely to become increasingly common as the years go by.

Generally the management and breeding of reptiles and amphibia in zoos, however, is a new field compared with mammal and bird husbandry, and generally little attention has been given to threatened species. Honegger (1975) gives four reasons for their lack of zoo breeding of reptiles. They are:

1) Specimens have often been kept singly in collections, with no possible mates.

2) The patterns of sexual dimorphism of the species are not always known.

3) The animals are unwittingly kept under conditions unsuitable for breeding, as the basic biological requirements are not always recognised.

4) Procuring the proper food for hatchlings is often extremely difficult, so that the total costs of incubation and raising offspring are rather high.

Nace (1977) pointed out that no efforts in the captive breeding of amphibians have been initiated with the express purpose of saving endangered populations. He states that, 'I know of only incidental attempts by zoos to use reproduction either to maintain their exhibit stocks, or to contribute to the conservation of endangered amphibian species'. The situation does not appear to have changed since then although the techniques for breeding exist. Maruska (in press) writes about the use of hormonal stimulants in the amphibian breeding programmes. He states that correct environmental conditions, which may include wet and dry periods, changes in photoperiod and temperature, or elevated humidity for particular species must be satisfied for hormonal induction to result in fertile eggs.

The breeding situation is more positive for rare reptiles and Jersey Zoo, for example, is active in ex situ conservation programmes. Since the Gaherty Reptile Breeding Centre was opened there in 1976, 20 species and subspecies have produced about 1115 live young of which 55 per cent have been reared (Bloxam & Tonge, in press).

Birds

As with other groups of animals, captive breeding of birds has tended to concentrate on relatively few species, chosen for factors other than their conservation status in the wild. Historically the captive breeding of birds for food no doubt came first, and birds have long been raised for their beauty and also for sport. Particular attention in captive breeding has been focused on groups such as the raptors and parrots. The role of private collections in the captive breeding of birds is well-established with hobbyists, societies and commercial aviaries maintaining a variety of species.

The achievements of zoos in ex situ bird conservation programmes are reviewed by Conway (1983). He points out that although more than 800 species of birds of 23 orders were bred in zoos according to the 1979 International Zoo Yearbook (IZY) census, few of the 433 birds with IUCN Red Data Book categories are housed in zoos. Only 37 listed species were bred. He considers the main limitations to be that most zoo facilities are poorly designed for bird propagation, the breeding of many threatened species is poorly understood, and some of the species are comparatively unattractive to zoo education and recreation programmes.

Co-operation between N. American living collections in breeding bird species is enhanced by annual surveys funded by The International Foundation for the Conservation of Birds (IFCB). The survey includes breeding by the larger bird collections in zoos and some private aviculturists in the U.S. and Canada. The information received on the numbers and sex of species held, breeding records, and the proportion of birds wild caught are computerised by the Zoological Society of San Diego. 1981 data revealed 26,077 birds of 639 species and subspecies in 123 collections. Twenty species were represented by only one individual in captivity (Muller, 1983).

Certain exotic birds which are commonly exhibited by zoos are still largely taken from the wild. This is the case for example with flamingos. Kear (in press) points out that the James flamingo, the rarest species of the group, is difficult to maintain healthy in captivity and has never bred. This may be due in part to feeding requirements and research is being carried out at the Wildfowl Trust Slimbridge Reserve in the U.K.

Much of the research on captive breeding of rare bird species has been carried out using close relatives of the species concerned. This is certainly the case, for example with raptors. In FWS programmes, Sandhill cranes (_Grus canadensis_) were studied in captivity in preparation for work on whooping cranes (_Grus americana_) and the Hispanolian Amazon (_Amazona ventralis_) was used to develop techniques used for the Puerto Rican Amazon (_A. vittata_) (Smart, 1983).

Models used for research purposes are not always adequate however. Kear (in press) points out, for example that, 'Currently arguments as to why particular wildfowl have problems in breeding or moulting are based largely on domestic fowl's response to photoperiods, and on refractoriness and moult research using passerines. Neither are probably good models for ducks and geese.'

An important new technique in the captive breeding of birds is the use of faecal steroid analysis as a method of bird sexing. This is invaluable as nearly one third of bird species are monomorphic, i.e. there are no readily distinguishable differences between the sexes (Cherfas, 1984). Other new developments include the use of artificial insemination, cryogenic preservation of spermatozoa, and cross-fostering using more commonly available species.

It is interesting to note that birds have a public appeal which has ensured research on the breeding of many species. This "public image" must not be underestimated when planning breeding programmes for the groups as has been shown by the much-debated work on the Californian condor. Those species which do not have commercial potential for "public support", often the less "attractive" groups, nevertheless have an important role to play in maintaining biological diversity and may be dependent on governmental support.

Mammals

The focus of zoos for centuries has been on the mammals ranging from the large and awe inspiring to the small and cuddly, the diversity in captivity has grown along with the talents and expertise of the employees. Conservation programmes have been successfully carried out _ex situ_ as for example at the Otter Trust and Rio de Janeiro Primate Center mentioned earlier. _Ex situ_ conservation of mammals is by no means comprehensive however.

Seal _et al_. (1977) reviewed the range of mammal taxa maintained in captivity, from ISIS data. They found the range of taxa represented covered 17 of the 19 mammalian orders (89 percent), 76 of 123 families (62 per cent), 363 of 986 genera (27 per cent) and 533 of 1986 species (13 per cent). Three orders - primates, carnivora and Artiodactyla - between them accounted for 80 per cent of all specimens, 85.5 per cent of all births and 79.5 per cent of all deaths. The Marsupialia, Rodentia and Perissodactyla accounted for 3.7, 5.9 and 4.0 per cent respectively of animals reported. Another six orders together account for 5.6 per of specimens held while the remaining seven (Monotremata, Dermoptera, Pholidota, Lagomorpha, Cetacea, Tubulidentata and Sirenia) covered less than one half per cent of all mammals held in captivity.

These percentages which remain similar today show the concentration on certain well represented taxa in zoos showing that there is far from a complete representation of mammals in captivity. This shows yet again that zoos must not be mistaken for alternatives or substitutes for the wild in the parameters understood today. They are no doubt the refuges from which we can build and secure the wild of tomorrow both in terms of what they hold (species) and even more likely in the expertise and facilities they can bring to bear.

NETWORKS AND INTERNATIONAL CO-OPERATION

Exchange of plants and animals for breeding purposes is of primary importance and the exchange of information on techniques of maintenance and propagation is also of great value. Co-operation between zoos is already well-established in the field of conservation. For botanic gardens formal networks related to conservation are more recent but serve to reinforce a tradition of exchanges of seed lists, living material and ideas. The International Association of Botanic Gardens was set up to encourage collaboration and interchange of ideas but only in recent years has conservation featured in their thinking. Discussion on the conservation role of botanic gardens has become incorporated into the role of IUCN.

i) IUCN

IUCN has from its inception been involved with captive breeding of threatened animals, through its Species Survival Commission (SSC). The majority of these Specialist Groups of the Commission have been involved in formulating species conservation plans which in many cases include captive breeding. In addition SSC has in particular a Captive Breeding Specialist Group. A number of Plant Specialist Groups have recently been established by SSC and it is expected that these will contribute to the debate on artificial propagation of rare and threatened plant species. See Annex for full list.

The CMC data base also holds information on the conservation status of animals compiled by the Species Conservation Monitoring Unit (SCMU). One of the outputs of SCMU is the IUCN Red Data Books which include summary information on captive breeding for each species. The Threatened Plants Unit (TPU) of CMC has already been mentioned. A third component of CMC, the Wildlife Trade Monitoring Unit compiles data on commercial trade and utilisation of wildlife and maintains a directory of "farming" operations.

All play an essential role in monitoring biological diversity and providing data to enable appropriate action programmes to be designed and implemented.

BGCCB

This body was set up in 1979 and as has been mentioned earlier it is co-ordinated by the Threatened Plants Unit of IUCN's Conservation Monitoring Centre. The Body now has 136 members. The Moscow Botanic Garden co-ordinates the response of 116 Gardens in the USSR for BGCCB.

Unfortunately representation of tropical countries is poor in the BGCCB with for example Montevideo Botanic Garden being the only S. American member. The BGCCB has circulated the following lists of threatened plants to its members and stores the information on holdings in the CMC computerised data base.

Europe	July 1978
Magagascan succulents	December 1979
Southern Africa	June 1980
Macaronesia	October 1980
Cycads	December 1980
S. Atlantic Is.	May 1981
Tree ferns (2 lists)	September 1981
New Zealand	December 1981
Australia	June 1982
W. Indian Ocean	August 1982
Hawaii	November 1982
Galapagos/Juan Fernandez Is.	February 1983
Europe (update)	March 1983
Mexican cacti	July 1983
India	November 1983
Euphorbia & Aloe of Africa	March 1984

A printout of each garden's holdings of rare plants is provided annually by BGCCB as discussed earlier. In an attempt to simplify and improve the exchange of data with IUCN and between individual gardens, BGCCB was recently carried out a questionnaire on the computerised garden record schemes of its members. This and other developments in ex situ plant conservation and strengthening BGCCB will be discussed at a forthcoming conference in the Canary Islands.

ii) American Association of Zoological Parks and Aquariums (AAZPA)

AAZPA is one of the regional associations of zoos, which are based in based in various parts of the world. It is distinguished by its size, influence and conservation successes. It is the professional organisation of the approximately 175 zoos and aquariums in the US and Canada (Foose, 1983b).

Conservation has been established as the highest objective of the AAZPA, which recognises that only through collective and co-ordinated efforts can zoos generate resources on a scale sufficient to save species. Conservation programmes are co-ordinated by Species Survival Plans (SSP) which have been initiated for over thirty species.

iii) The International Zoo Yearbook (IZY)

IZY has been published annually by the Zoological Society of London (ZSL) since 1960. It is the main international forum for exchange of information on the work of zoos and other centres involved on a range of topics including husbandry and breeding techniques. The Proceedings of the Second and Third World Conference on Breeding Endangered Species in Captivity have been included in Volumes 17 and 20 respectively. Proceedings of the Fourth Conference in the series will be published in volume 14.

In addition each volume of the Yearbook includes a Reference Section which incorporates an international directory of zoos and aquaria, a taxonomic list of vertebrate species bred in captivity for the year, two years prior to publication and a census of rare animals in zoos. Details of Studbooks are also included. The IZY is thus a primary source of information in planning conservation collections and is an ongoing record of the biological diversity maintained by zoos. The recording system used in the compilation of the Yearbooks is not yet computerised and this we feel would greatly help in this vital work. The interchange of data is so essential in the development of conservation programmes.

iv) Studbooks

A studbook is an international register which lists and records all captive individuals of a species which is rare or endangered in the wild. The concept, initially developed for the selective breeding of domestic animals, was first used on a wild species, the European bison in 1932. Studbooks are now kept for about 40 endangered species and are an invaluable tool in international co-operation in captive breeding. Official studbooks are those recognised and endorsed by IUCN, SSC and IUDZG and are co-ordinated by the editor of IZY. This concept is one which should be encouraged for many other major groups of animals. In some cases additional assistance is needed to help the hard pressed stud book keepers in their work.

v) ISIS

The International Species Inventory System (ISIS) is a programme of AAZPA, in collaboration with Federal agencies and private foundations, to develop a census and vital statistics inventory system for wild animals held in zoos (Seal et al., 1976). ISIS contributes another important element in the zoo world's approach to species diversity, so far it is mainly confined to the US.

vi) IUDZG

International Union of Directors of Zoological Gardens, is an essential international network providing guidance on formal and informal agreements for breeding many zoo species. Their power is important in many large captive breeding programmes.

CONSERVATION RESEARCH IN LIVING COLLECTIONS

Living collections of plants and animals provide opportunities for the study of species in controlled environments. This has implications for the conservation of biological diversity both in the wild, in semi-natural and in highly managed situations. As yet however, a relatively small proportion of the research of zoos, botanic gardens and similar institutions is directed towards conservation. Research on living collections tends rather to reflect the diverse range of research interests of individual scientists and departments.

Some zoos and botanic gardens also provide staff with opportunities for field research which can yield valuable information on rare plants and animals *in situ*. At a more basic level botanic gardens are often involved in the preparation of preliminary species checklists. This must be the fundamental task of botanic gardens in tropical and subtropical regions where floristic information is generally still scant.

Bramwell, (1981), has discussed the role of local botanic gardens in conservation-orientated research. He points out that the first step in conservation research must be, 'the provision of adequate information on basic floristics and species distribution'. The follow-up to this should be the identification and mapping of threatened and endangered species with action plans to save them. Ecological studies are also of fundamental importance. 'A great deal of basic information is lacking on most aspects of our endangered plants, on habitats, niches, predators and so on, all vital for successful maintenance of such plants both in the botanical garden and in habitat reserves' (Bramwell, 1981).

In the *ex situ* situation the importance of basic observation is particularly vital for both rare plants and animals which may be extremely difficult to locate and study intensively in the field. Remarkably little is still known for example of the breeding mechanisms of plants. Living collections, particularly when plants are grown under near natural conditions provide opportunities for studying reproductive biology, for example, through observation of pollination mechanisms and pollinators.

Examples of specific research projects directed at the conservation of particular species include the current work of the University Botanic Garden, Cambridge, on the fen violet (*Viola persicifolia*) in cultivation and in its natural habitat at nearby Wicken Fen. *Orothamnus zeyheri* has been studied intensively, in the field and in the cultivation by the Kirstenbosch Botanic Garden in South Africa.

The complexity of the maintenance needs and breeding requirements of rare animals in captivity is such that research needs for *ex situ* conservation have scarcely been satisfied. Benirschke (1983) argues for greater research in zoos as an aid to conservation and for continuing co-operation with scientists working in other institutions. He draws attention for example to the application of knowledge of human medicine to captive reproduction. Current work includes the use of ultrasonography amniocentesis in gorilla pregnancies, modern antibiotics for therapy against infections, identification of different steroid pathways in endocrine monitoring, and mitochondrial DNA study in the investigation of subspecific status of selected species. Further research is essential in the continuance of ex situ conservation. At the same time basic ecological research must be continued and for the lower orders of animals inventory work on the classification, distribution and preparation of threatened species lists stepped up.

CONSERVATION EDUCATION IN LIVING COLLECTIONS

One of the primary conservation roles of living collections is in education. All botanic gardens and zoos regardless of their size, aims, funding or research capabilities have the opportunity to educate merely by displaying plants and animals which the majority of visitors would not normally see elsewhere. Sadly as yet, active conservation education by zoos and botanic gardens has scarcely been developed. There are however notable exceptions such as San Diego Zoo where conservation is a major theme of the guided tours and at Jersey Zoo as discussed earlier. Displays are all too often not related to the wild situation at all and an important opportunity for conservation education is therefore sadly missed.

The conservation education of living collections can take on many forms. At one level it can show local people the richness of their own fauna and flora. This is particularly important in the developing world where, for example, in Madagascar, inhabitants may have no idea that their wildlife is unique and internationally recognised as an invaluable asset. In the developed world also zoos may provide the only opportunity for visitors to see locally rare species at close range, as, for example, at the Otter Trust headquarters in the U.K.

Zoos and botanic gardens may contribute directly to lessening threats to wild species. One of the aims of the Madras Snake Park in India has, for example, been to show the public that the majority of snakes are non-poisonous and should not therefore be attacked on sight. The park provides school educational programmes including lectures, radio talks and TV films aimed at creating interest in the young. The finance is derived from the visitors to the park, government grants and other donors (Seshadri, 1984).

Clearly good educational facilities at zoos and botanic gardens may lead to increased public funding for conservation. Zoos and botanic gardens are highly visible, often being situated in, or close, to major cities, and advertised as tourist attractions. People generally like to see the results of their charitable donations and the integrated conservation programmes of living collections provide for this. Births of endangered mammals in captivity are clearly a visible sign of conservation success. At the same time less resources may be required to show, through displays and leaflets, the field work associated with conservation programmes.

It would seem that botanic gardens have been particularly slow in fulfilling their potential in conservation education, despite the fact that they have long been associated with centres of learning. There are however, notable exceptions with, for example, a permanent display bed of British threatened plants maintained at the University Botanic Garden, Cambridge, with leaflets on sale and the importance of conservation education recognised at Jardin Botanico 'Viera y Clavijo' Gran Canaria and the botanic garden at Xalapa, Mexico. Included in the main aims of the Xalapa Botanic Garden are 'to display the regional flora; to initiate public interest in the care of and respect for wildlife generally; to demonstrate good land use through vegetable gardening; terracing and composting, to be an educational centre for all levels from kindergarten to post-graduates' (Vovoides, 1979).

One of the most exciting developments in the conservation education offered by living collections, has been an integrated approach showing the inter-relationships between plants and animals and their maintenance in an ecologically 'healthy' environment. The development of this type of approach has involved close co-operation between zoos and botanic gardens as is shown, for example by Edinburgh's Interlink programme in the U.K.

As part of a range of courses involving a number of institutions in Edinburgh, an Interlink course entitled 'Going, Going, Gone', focused on the loss of biological diversity. The course includes visits by school children to the Royal Botanic Garden, Edinburgh, to see threatened plants, learn how they can be conserved in botanic gardens, visits to the zoos to see ex situ animal conservation, and visits to a local RSPB nature reserve.

The Lincoln Park Zoological Gardens, Chicago also runs an integrated conservation education programme using both the zoo and conservatory. In the ecological teaching the inter-relatedness of plants and animals is stressed (Meritt, in litt., 1984). The emphasis is on the conservation of tropical species and a co-operative project with WWF-US has produced educational materials on the tropical rain forest.

Education is one aspect of conservation which zoos and botanic gardens all must be encouraged to develop. Resources are often present, particularly in the larger institutions, through planning, publicity or education departments, or can be brought in through co-operation with other institutions or conservation organisations. At the very least all institutions should strive to indicate on labels which taxa are of conservation concern and to include some conservation information in souvenir booklets or guides.

LIMITATIONS

Given sufficient resources of expertise, finance and space, there is no doubt that a significant proportion of the world's biological diversity could be maintained in living collections. Sufficient resources are not available however and are unlikely ever to become so, in part because ex situ conservation is considered to be "second-best". Manipulation of wild plants and animals is seen by some as alien to the conservation of nature and too many see conservation generally as an expensive luxury. In situ conservation should rightly be given priority but many of the current limitations of in situ conservation could be solved by additional funding together with a more determined and co-ordinated approach.

The sheer number of species under threat in the wild limits the overall effectiveness of ex situ conservation. Selecting which species should be conserved in living collections is a major problem. Selection has generally been on an extremely ad hoc basis, dependent primarily on the whim and skill of individuals. Too much still depends on a handful of people and it is important that responsibility for maintaining rare species becomes institutionalised on a long term basis. The strength of any institution as has already been said, is really only the sum total of its skilled employees after physical resources have been provided. Building of skilled and dedicated teams must be an essential element in institutional policy.

BIOLOGICAL LIMITATIONS

Given the need to manage plants and animals in an artificial environment, a fundamental problem is the lack of basic biological knowledge on which to base management decisions. Baseline ecological research is a prerequisite for maintaining wild animals and plants in captivity and to ensure their propagation. All too often very little is known about the ecology of rare and threatened species in the wild. Only limited information is available on breeding strategies under natural conditions and the genetic principles of captive breeding are only now becoming understood.

The problems of maintaining small numbers of a species in isolated conditions have been predicted and evidence is now becoming available from a range of studies. It should be remembered as a starting point that endangered species will already have suffered genetic erosion in the wild and so only a limited range of intra-specific variation is available for sampling.

Much more attention is now given to the geographic provenance of specimens collected for zoos and botanic gardens, a factor which has been too often overlooked in the past. There has been considerable debate about the importance of maintaining intact populations of sub-specific taxa in captivity. Connie Greig (1977) has argued that, 'A very important function of genetic conservation is the prevention of genetic panmixia', and that, 'The separate maintenance of the genetic integrity of each component ecotype of a species must be our aim'. This is clearly of prime importance where re-introduction into the natural habitat is planned. Where a species is on the brink of extinction however the prevention of panmixia may be of secondary importance compared with bulking up the number of viable individuals.

It is generally accepted that the size of a founder population for establishing a species in a living collection should be as large as possible. For animals, five to ten pairs may be sufficient, assuming that these are unrelated, non inbred and interfertile (Foose, 1983a). For plant species the size of a founder population will depend on both the amount and nature of the material available in the wild. Hawkes (1976) points out that, 'In general it is much better to collect seeds, since they represent a much wider sample of the gene pool, weight to weight, than other parts of the plant'. Discussing the ideal quantities of seed to be collected he considers that, 'The plant explorer should endeavour wherever possible to take bulk seed samples from up to about 50 individuals and certainly no more than 100. Samples should be clustered and the clusters should be spread as evenly as possible throughout the collection area'. Clearly this may not be possible for all rare and threatened plant species and the quantity of seed collected will depend in part on storage facilities.

The main genetic problems associated with maintaining small 'captive' populations of animals or plants are inbreeding depression, artificial selection and genetic drift. Inbreeding depression has only recently been recognised as a problem with zoo animals and there are still some who consider that its effects are exaggerated. The extent of the problem has however been shown by Ralls & Ballou (1983) from an analysis of the breeding records of 44 species at the National Zoological Park, Washington (NZP). The species concerned were sixteen ungulates, sixteen primates and twelve small mammals. It was found that, 'juvenile mortality of inbred young across taxa was higher than that of non-inbred young in forty-one of the forty-four species'.

Ralls & Ballou (1983) point out that most captive animal populations were founded before the need for genetic managment became apparent and have developed characteristics unsuited to the development of captive self-sustaining populations. Even breeding programmes which have been widely considered successful are now seen to be 'genetically unhealthy'. The Dorcas gazelle herd, for example, has now been shown to exhibit two typical deleterious inbreeding effects, increased juvenile mortality in inbred calves and delayed sexual maturity in inbred calves.

The effects of inbreeding in plant populations depend on the breeding system. In general self-pollinating species show less inbreeding depression than do out-crossing forms (Frankel & Soulé, 1981). Given the inherent heterozygosity of most flowering plants artificial selection is a more pressing problem faced in the maintenance of species than the effects of inbreeding.

Processes of artificial selection clearly start with the establishment of founder populations. From that point onwards the animals or plants will be subject to an environment substantially different to their natural habitat and without the normal factors of competition. The longer a species is maintained in captivity the more "domesticated" it will become and less fitted for potential return to the wild.

Genetic drift has been defined as, 'change changes in allele frequencies as a result of random sampling among gametes from generation to generation', (Hartl, 1980). Such a process will lead to loss of variability and because small samples are not representative, genetic drift has a greater effect on small populations. Documented examples of the effects of genetic drift in captive populations of rare species are difficult to come by. For animals a more fundamental problem in captive populations is to ensure reproduction at all. Problems of compatibility between individuals of some species limit the likelihood of mating to a critical level. Even more serious is the failure of second-generation breeding in some species. Conway (1980) points out that only a few animals have been maintained for long periods in zoos, and cites the orang-utan as an example of a species which has not reached second-generation breeding in captivity. This is not thought to be due to genetic and demographic problems but to behavioural and also unidentified physiological and developmental insufficiencies.

For such reasons Conway (1980) points out that biologists are, 'using an increasing number of manipulative techniques to enhance reproductive success'. Long term maintenance of rare plants and particularly animals is still a hit and miss affair relying on increasingly sophisticated research. In the field of cryogenic sperm and embryo banks, for example, Foose, Seal and Flesness (1985) point out that, 'Specialists in animal reproductive technology point out that anything up to two centuries of research may be necessary before such techniques become generally applicable' - the authors hope this situation is an exception.

In the *ex situ* conservation of plant species there are still many difficulties to be overcome, for example in the storage and germination of seed. Orchids are dependent on mycorrhizal fungi for their germination and *in vitro* germination using cultured fungi is now being investigated.

In a discussion of the conservation of tropical rain forest, Whitmore (1980) points out that, 'Storage of seed is expensive and is, at present, technically impossible for the (probably) large fraction of climax forest, trees with recalcitrant seeds - unstorable by drying and chilling'. It is the tropical forest ecosystems which present the most urgent and pressing problems to conservationists, problems which have scarcely been and can scarcely be addressed by *ex situ* conservation. This situation is discussed further below.

OPERATIONAL LIMITATIONS

The success of *ex situ* conservation on an international scale is severely limited by the availability and distribution of resources. The finance and skills are concentrated in a relatively small number of institutions nearly all located in the developed world. There is a pressing need to revitalise existing or establish new botanic gardens in the Tropics and also to establish animal breeding centres for threatened species. Ideally both should be associated with local protected areas and should as far as possible be self-financing. Supportive collaborating institutions should be found, to provide technical and scientific skills and additional sources of funding Aid agencies may well find such collaborative ventures attractive.

Securing adequate funds for conservation work appears to be a problem shared by the majority of zoos and botanic gardens. Knowles (1977) points out that deficit financing exists whenever a zoo maintains more animals than are strictly necessary to putting on a show. This applies particularly to the many zoos which receive no municipal or governmental funding but rely solely on the takings of visitors. The majority of people who visit zoos do so for entertainment rather than education so the breeding of relatively obscure and unattractive animals is unlikely to attract more visitors and hence more funding. The provision of educational displays is likewise unlikely to attract more paying members of the public and is therefore a further drain on financial resources.

Knowles (1977) also drew attention to the expense involved in procuring endangered animal specimens for captive breeding programmes. He estimates that in order to comply with relevant legislation, in a direct sale between one zoo and another, transport expenses are likely to amount to between 10-20 per cent of the value of the animal. Where the cost of quarantine and a double set of movements is added, together with the dealer's profits this figure may have risen by 80 per cent. For some animals, particularly herd species which need to establish a hierarchical system for successful reproductive activity, relatively large numbers must be procured for breeding purposes.

Clearly the maintenance of healthy breeding animal populations in captivity is an expensive role for zoos particularly where skilful manipulative techniques are required to ensure reproduction. The artificial propagation of endangered plant species is a less costly undertaking but still takes a comparatively high proportion of the relatively low budget allotted to botanic gardens. Botanic gardens are unlikely to be able to command the entrance fees of zoos and if open to the public at all are likely to need to spend a high proportion of their budget on maintaining attractive amenity displays.

In order to facilitate the exchange of material between zoos or botanic gardens involved in co-operative conservation ventures a common system of health and conservation laws would be beneficial. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is the main conservation agreement relevant in this context. Provisions are included in the treaty to allow for the exchange of material between scientific institutions but because of national interpretations of CITES it may have acted as a limitation to co-operative breeding in some instances.

Together with the need to exchange animals and plants for the maintenance of breeding populations in captivity there is a need also to exchange skills and co-operate in training programmes. At present the lack of skilled personnel is one of the main limiting factors in _ex situ_ conservation especially in developing countries.

In the traditional zoos of the developed world space may be a severe limitation on the establishment of breeding populations. The zoos designed to display small numbers of a diverse range of species and often in urban locations cannot accommodate the numbers now considered necessary for _ex situ_ conservation. Co-operation between zoos again becomes essential and certain zoos have found additional sites. Examples are provided by NZP's Conservation and Research Centre at Front Royal, Virginia and St. Catherine's Island Survival Centre of NYZS. Co-operative arrangements have also been developed with private establishments such as the (SSP) project to maintain Grevy's Zebra (Equinus grevyi) on a Texan range (Foose, 1983a).

Even where resources are available for ex situ conservation, political considerations may act as a constraint. The internal policies of the institution and external politics, particularly if the institution is part of a Government Department, will clearly influence the long term success of any conservation undertakings. Political decisions may fluctuate so widely that sustainable breeding populations cannot be maintained. Where the institution has a high public profile at local, national or international level, it may be relatively immune from changes of political whim but equally may suffer criticisms if success is not constantly achieved.

The lack of financial support for the majority of Tropical Botanic Gardens is a major worry and one which needs serious review. The role of such gardens can be at at least three levels - a) local education to show a country's wealth, beauty and good conservation practices b) provide support for local plant conservation programmes both in situ and ex situ and even more importantly c) aid with the development of local horticultural institutions - and other economic plant development programmes. There are all areas which can aid in the development of a country and should not be seen as a luxury.

At an international level the obvious imbalance of financial and scientific resoures between different countries must be avoided by building up joint ventures with local training and financial suppport for local success. In conservation local political problems are often the most difficult and retractable to solve. Sadly they may cause more species crashes than direct pressure from people and their various activities. This element must not be left out of planning strategies to maintain diversity - too many theories founder on reality.

To obviate many of the problems discussed above joint ventures with interrelated field and zoo or field and botanic garden projects should be encouraged at all levels. A zoo or botanic garden 'go it alone' approach to conservation is unrealistic and doomed to failure in the longer term. Prospects for success are increased by a mixture of approaches and can help to prevent short term (evolution-wise) setbacks. Collaborative schemes maximise the resources and options available.

RECOMMENDATIONS

1) Living collections have an important role to play in the conservation of biological diversity and should be fully incorporated into all conservation planning, at all levels.

2) The potential of living collections as elements in the conservation of taxa is by no means fully realised. The levels of funding and co-operation between collections, the management and aims of collections are the main limiting factors at present.

3) Co-operation between botanic gardens should be encouraged at a regional level for example through the Center for Plant Conservation in the US, at international level through further development of the activities of IUCN's BGCCB. This Body should promote much closer links between ex situ and in situ plant conservation programmes.

4) Co-operation between zoos should be maintained and encouraged with particular emphasis on drawing further institutions into the current networks. Research, breeding and training programmes should be integrated between zoos to a much greater degree.

5) Links between zoos and botanic gardens should be encouraged with a particular emphasis on the cultivation of rare and threatened plants by horticultural staff of zoos and integrated conservation education programmes. To this end AAZH should be expanded and encouraged to join the BGCCB. Conversely many botanic gardens could well provide a home for certain animal species without detriment to their horticultural programmes.

6) The gradation and links between the wild, semi-natural and heavily managed situations should be fully recognised and encouragement given to the optimum development and use of practical skills in the maintenance of rare species in all cases.

7) IUCN should develop an ex situ conservation group of SSC. This would include commercial horticulturists, zoo and botanic garden managers together with managers of recreated habitats and man-made preserves.

8) Funding by both Governmental and Non-Governmental bodies should promote training in practical horticultural and breeding skills in both zoos and botanic gardens for conservation purposes. The emphasis should be placed on training for those from the tropics, in the skills necessary to cope in the tropics with tropical conservation problems.

9) Local botanic gardens and captive breeding programmes should be established in tropical and subtropical regions, designed as far as possible to be self-financing for example in the botanic garden context through the sale of propagated material.

10) The development of partnerships between tropical and temperate institutes to pool expertise, to encourage staff interchange and training and joint funding ventures may also help improve the maintenance of biological diversity.

11) A strong emphasis should be placed on public education by zoos and botanic gardens relating exhibits to the wild situation as far as possible. In the long term this should lead to increased public funding and awareness of the environment and its needs. Biological diversity is not merely a convenient phrase but the very web of life of the animal and plant kingdom.

REFERENCES

Ayensu, E. and DeFillips, R.A. "Endangered and Threatened Plants of the United States", Washington DC., Smithsonian Institution Press, 1978.

Benirschke, K., "The Impact of Research on the Propagation of Endangered Species in Zoos", Genetics and Conservation, Schonewald-Cox, C., et al., (eds), Menlo Park, California, Benjamin/Cummings Publishing Co., 1983. pp. 402-413.

Bloxam, Q.M.C. and Tonge, S.J., "Breeding Programmes for Reptiles and Snails at Jersey Zoo", Proceedings 4th World Conference on Breeding Endangered Species in Captivity, Harderwijk, Netherlands, Sept. 24-27, 1984, in press.

Bouvarel, P., "The Conservation of Gene Resources of Forest Trees," Genetic Resources in Plants - their Exploration and Conservation., Frankel, O.H. and Bennet, E. (eds), Oxford, Blackwell Scientific Publications, IBP Handbook No. 11, 1970, pp. 523-529.

Bramwell, D., "A Local Botanic Garden: Its Role in Plant Conservation," Survival or Extinction, Proceedings Conference Royal Botanic Gardens, Kew, 1978, Synge, A.H.S. and Townsend, H. (eds), Kew, Bentham Moxon Trust, 1979, pp. 47-52.

Bramwell, D., "Conservation-orientated Research in local Botanical Gardens", Bot. Jahrb. Syst. 102 (1-4): 125-132, 1981.

Bustard, H.R. "Captive Breeding of Crocodiles", The Care and Breeding of Captive Reptiles, British Herpetological Society, 1980.

Cherfas, J. Zoo 2000, London, BBC, 1984, 244 pp.

Clegg, M.T. and Brown, A.H.D. "The Founding of Plant Populations", Genetics and Conservation, Schonewald-Cox, C. et al., (eds), Menlo Park, California, Benjamin/Cummings Publishing Co., 1983, pp. 216-228.

Comrie Grieg, J., "The Principles and Problems of Genetic Conservation in Relation to Wildlife in South Africa", Jonkershoek Native Conservation Station, unpublished report.

Conway, W.G., "An Overview of Captive Propagation", Conservation Biology: An Evolutionary-Ecological Perspective, Soulé, M.E. and Wilcox, B.A. (eds), Sunderland, Massachusetts, Sinauer Associates, Inc. 1980.

Conway, W.G., "The Summing-up", Proceedings Jean Delacour - IFCB Symposium on Breeding Birds in Captivity, 1983.

Dmoch, R. "Guide Book of the Zoological Gardens of Frankfurt am Main", Zoological Gardens Frankfurt (undated)

Durrell, G. & Durell, L.M. "Breeding Mascarene Wildlife in Captivity", International Zoo Yearbook 20: 112-119, 1980.

Erickson, R.C., "Propagation Studies of Endangered Wildlife at the Patuxent Center", International Zoo Yearbook 10: 40-47, 1980.

Esser, K. "Genetic Factors to be considered in Maintaining Living Plant Collections", Conservation of Threatened Plants, Proceedings Conference Functions of Living Plant Collections in Conservation and Conservation-orientated Research and Public Education, Royal Botanic Gardens, Kew, 1975, Simmons, J. et al. (eds), New York, Plenum Press, 1976, pp 185-198.

Foose, T.J., "The Relevance of Captive Populations to the Conservation of Biotic Diversity, "Genetics and Conservation, Schonewald-Cox, C., et al., (eds), Menlo Park, California, Benjamin Cummings Publishing Co., 1983a, pp. 374-401.

Foose, T.J., "Captive Propagation of Sumatran Rhinoceros. A Proposal:, AAZPA, 1983b.

Foose, T.J., Seal, U.S. and Flesness, N.R., "Conserving Animal Genetic Resources", IUCN Bulletin 16 (1-3): 20-21, 1985.

Frankel, O.H., "Genetic Conservation in Perspective", Genetic Resources in Plants - their Exploration & Conservation, Frankel, O.H. and Bennett, E. (eds), Oxford, Blackwell Scientific Publications, IBP Handbook No. 11, 1970, pp. 469-489.

Frankel, O.H., "The Time Scale of Concern", Conservation of Threatened Plants, Proceedings Conference Functions of Living Plant Collections in Conservation and Conservation-orientated Research and Public Education, Royal Botanic Gardens, Kew, 1975, Simmons, J. et al. (eds), New York, Plenum Press, 1976, pp. 245-257.

Frankel, O.H., and Soulé, M.E., "Conservation and Evolution", Cambridge, Cambridge University Press, 1981, 327 pp.

Hall, A.V. and Rycroft, H.B., "The Conservation Policy of the National Botanic Gardens and its Regional Gardens", Survival or Extinction, Proceedings Conference Royal Botanic Gardens, Kew, 1978, Synge, H. and Townsend, H. (eds), Kew, Bentham Moxon Trust, 1979 pp. 125-133.

Hawkes, J.G., "Sampling Gene Pools, Conservation of Threatened Plants, Proceedings Conference Functions of Living Plant Collections in conservation and conservation-orientated Research & Public Education, Royal Botanic Gardens, Kew, 1975, Simmons, J. et al. (eds), New York, Plenum Press, 1976, pp. 245-257.

Honegger, R.E., "Breeding and Maintaining Reptiles in Captivity", Breeding Endangered Species in Captivity, Martin R.D. (ed), London, Academic Press, 420 pp., 1975.

Hutton, A.F., "Butterfly Farming in Papua New Guinea", Oryx 19: 158-162, 1985.

Kear, J., "Captive Breeding Programmes for Waterfowl and Flamingoes", Proceedings 4th World Conference on Breeding Endangered Species in Captivity, Harderwijk, Netherlands, Sept. 24-27, 1984, in press.

Knowles, J.M., "The economics of breeding endangered species", International Zoo Yearbook 17: 20-25, 1977.

Maitland, P.S. and Evans, D., "The Role of Captive Breeding in the Conservation of Fish Species", Proceedings 4th World Conference on Breeding Endangered Species in Captivity, Harderwijk, Netherlands, Sept. 24-17, 1984, in press.

Mallinson, J., "Lion tamarins' survival Hangs in Balance", Oryx 18: 72-78, 1984.

Maruska, E.J., "Amphibians: Review of Zoo Breeding Programme", Proceedings 4th World Conference on Breeding Endangered Species in Captivity, Harderwijk, Netherlands, Sept. 24-27, 1984, in press.

Meritt, D.A., Lincoln Park Zoological Gardens, Chicago, in. litt., 1984.

Morton, A.C., "Butterfly Conservation - the need for a Captive Breeding Institute", Biological Conservation 25: 19-33.

Muller, K.A., "Observations on the Bird Breeding Survey as a Management Tool", Proceedings Jean Delacour - IFCB Symposium on Breeding Birds in Captivity, 1983.

Nace, G.W., "Breeding Amphibians in Captivity", International Zoo Yearbook 17: 44-50, 1977.

Ralls, K. and Ballou, J., "Extinction: Lessons from Zoos", Genetics and Conservation, Schonewald-Cox, C. et al., (eds), Menlo Park, California, Benjamin/Cummings Publishing Co., 1983, pp. 164-184.

Richardson, S.D. "Gene Pools in Forestry", Genetic Resources in Plants - their Exploration and Conservation, Frankel, O.H. and Bennet, E. (eds), Oxford, Blackwell Scientific Publications, IBP Handbook No. 11, 1970, pp. 353-365.

Seal, U.S. et al., "ISIS: a computerised record system for the management of wild animals in captivity", International Zoo Yearbook 17: 68-79, 1977.

Seal, U.S.; Makey, D.G.; and Murtfeldt, L.E., ISIS: an Animal Census System. International Yearbook 16: 180-184, 1976.

Seshadri, D., "To Save the Snake: Education and Conservation at the Madras Snake Park", Oryx 18: 79-81, 1970.

Simmons, J. et al. (eds), 'Conservation of Threatened Plants", Proceedings Conference Functions of Living Plant Collections in Conservation and Conservation-orientated Research and Public Education, Royal Botanic Gardens, Kew, 1975, New York, Plenum Press, 1976.

Smart, G., State of Fish and Wilidlife Service's Endangered Species Research Program", Proceedings Jean Delacour - IFCB Symposium on Breeding Birds in Captivity, 1983.

Synge, A.H.M.S. and Townsend, H. (eds). "Survival or Extinction", Proceedings Conference, Royal Botanic Gardens, Kew, 1978, Kew, Bentham Moxon Trust, 1979.

Thibodeau, F.R. and Falk, D.A., "The Center for Plant Conservation: Programme Development Plan and Budget", undated.

Vovoides, A.P., "Mexico: Practical Conservation Problems of a New Botanic Garden", Survival or Extinction, Proceedings Conference, Royal Botanic Gardens, Kew, 1978, Synge, A.H.M.S. and Townsend, H. (eds), Kew, Bentham Moxon Trust, 1979, pp. 117-123.

Walters, S.M., "The Eastern England Rare Plant Project in the University Botanic Garden, Cambridge, "Survival or Extinction, Proceedings Conference Royal Botanic Gardens, Kew, 1978, Synge, A.H.S. and Townsend, H. (eds), Kew, Bentham Moxon Trust, 1979, pp. 37-46.

Walters, S.M., "The Role of European Botanic Gardens in the Conservation and Rare and Threatened Plant Species", Gartn.-Bot. Brief 51.

Walters, S.M. and Birks, H., "Botanic Gardens and Conservation", Gland, WWF, WWF Plants Campaign - Plantpac No. 5, 1984.

Watre, P., "Otter Havens in Norfolk and Suffolk, England", Biological Conservation 16(1): 73-81, 1979.

Whitmore, T.C., "The Conservation of Tropical Rain Forest", Conservation Biology: An Evolutionary-Ecological Perspective, Soulé, M.E. and Wilcox, B.A. (eds), Sunderland, Massachusetts, Sinauer Associates, Inc., 1980.

Wochok, Z.S., "The Role of Tissue Culture in Preserving Threatened and Endangered Plant Species", Biological Conservation 10: 83-89.

Wolters, J., "The role of private collections, universities and research centres in breeding programmes for threatened species", Proceedings 4th World Conference on Breeding Endangered Species in Captivity, Harderwijk, Netherlands, Sept. 24-17, 1984, in press.

Woods, A. and Miller, K. "Kew Propagation News". Threatened Plants Newsletter No. 12 :7, 1983.

Appendix 1.

Species Survival Commission Specialist Groups

SSC African Elephant and Rhino Group
SSC African Equid Group
SSC Amphibian Group
SSC Ant Specialist Group
SSC Antelope Group
SSC Asian Elephant Group
SSC Asian Rhino Group
SSC Australasian Marsupial Group
SSC Australasian Plant Group
SSC Bear Group
SSC Butterfly Group
ICBP Group on Birds of Prey and Owls
ICBP Group on Bustards
SSC Cacti and Succulents Group
SSC Canid Group
SSC Captive Breeding Group
SSC Caprinae Group
SSC Cat Group
SSC Cave Species Group
SSC Central America Plant Group
SSC Cetacean Group
SSC China Plant Group
ICBP Group on Cranes
SSC Crocodile Group
SSC Cycad Group
SSC Deer Group
SSC European Bison Group
SSC European Plant Group
SSC Ethnobotanical Group
SSC Ethnozoology Group
SSC Fern Group
SSC Fish Group
IWRB/ICBP Group on Flamingos
SSC Fresh Water Chelonia Group
ICBP Group on Gallifornes
SSC Genome Conservation Group
ICBP/IWRB Group on Herons
SSC Hippo Group
ICBP Hornbill Group
SSC Hyaene Group
SSC Indian Sub-continent Plant Group
SSC Introductions and Re-introductions Group
SSC Island Plant Groups
SSC Lagomorph Group
SSC Marine Turtle Group
SSC Mullusc Group
SSC Odonate Group

SSC Orchid Group
SSC Otter Group
SSC Palm Group
ICBP Group on Parrots
ICBP Group on Pelicans
ICBP Group on Piciformes
SSC Pigs and Peccaries Group
SSC Polar Bear Group
SSC Primate Group
SSC Procyonid Group
SSC Rodent Group
ICBP Group on Sea Birds
SSC Seal Group
SSC South American Camelid Group
SSC South American Plant Group
SSC Sirenia Group
ICBP Group on Storks, Ibises and Spoonbills
SSC Tapir Group
SSC Tortoise Group
SSC Trade Specialist Group
SSC Veterinary Group
IWRB Waterfowl Group
SSC Wild Cattle Group
SSC Wolf Group

Appendix 2

CODE OF CONDUCT FOR GROWERS AND COLLECTORS OF SUCCULENT PLANTS

Introduction

IOS* was probably the first organization devoted to a particular plant group to publish a Code of Conduct, and the original edition (1974) has been reprinted in various national cactus magazines and in several translations, including Russian. It was also the starting-point for the Code published in 1979 by the Cactus and Succulent Society of America.

Delegates to a conservation seminar at the XVII IOS Congress in Vienna, August 1982, called for a new edition of the IOS Code to reinvigorate the campaign to reduce pressure on wild populations by persuading hobbyists not to buy unpropagated wild-collected specimens offered for sale by traders and retailers.

The new Code repeats many of the 'do's and don'ts' of the previous edition but is expanded to draw attention to legal controls on trade, and to provide a list of the species in which international trade is prohibited.

Laws to protect threatened species cannot, by themselves, save the plants. Awareness, goodwill and concern among all who are interested in cacti and other succulents, whether scientifically, commercially or as amateurs, is vital, and the past decade has seen several developments, besides the introduction of legal controls, which encourage the hope that trade in wild plants may gradually cease to be a threat to many choice and slow-growing species: Hobbyists are more aware of the need to think about the survival of species in the wild, and the greenhouse stocked with expensive 'imports' is nowadays a matter for shame, not pride; nurserymen have improved the range and quality of seed-grown plants to such an extent that the wildling, often scarred, rootless and difficult to establish, is a very poor bargain in comparison; and the good habit of recording the seed-source, which goes some way towards a guarantee of 'pedigree', is also spreading among suppliers and collectors and lessening the mystique once exclusively enjoyed by field-collected plants.

As the previous edition of this Code recognized, the threat posed by trade in wild plants to the survival of choice species, though serious and selective, is not so massive, so indiscriminate or so hard to counteract, as Man's wholesale destruction, for whatever reason, of the habitats where the plants grow naturally. A final section of this leaflet briefly assesses conservation action in this wider context, and lists sources of further information.

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* *The International Organization for Succulent Plant Study: one of the Commissions of the International Union of Biological Sciences, composed of botanists and professional and amateur growers in some 25 countries. This leaflet has been compiled for IOS by David Hunt & Sara Oldfield, The Herbarium, Royal Botanic Gardens Kew, Richmond, Surrey TW9 3AE, England, from whom further copies can be obtained.*

CODE OF CONDUCT

To the Collector in the Field

Before collecting anything:

DO acquaint yourself with national and state controls, and find out which species are protected.

DO obtain all necessary permits, both for collecting and for export and import to other countries.

DO notify interested local organizations of your intentions.

Then:

DO strictly observe restrictions on what may be collected (which species, how many specimens, what kind of material). Where possible, collect seed, offsets or cuttings, not the whole plant.

DO leave mature plants for seed production. They are needed to perpetuate the wild population, and are unlikely to transplant successfully.

DO collect discreetly; DON'T lead local people to believe the plants are valuable, or encourage or pay them (or their children) to collect for you.

DO make careful field-notes, including precise locality, altitude, type of vegetation and soil, date of collection and your own field number. Try to assess the number of individuals and extent of the population, the amount of seed-setting and the frequency of seedlings.

DO note possible threats to the habitat, e.g. through grazing, drainage or cultivation, urban spread or road-widening.

DO take photographs and/or preserve representative herbarium material. Submit this material, with a copy of your notes, to an appropriate institution or organization.

DON'T underrate the value of your field observations: carefully recorded they will be a useful contribution to science and to conservation.

IF... you plan to collect in commercial quantities, DON'T

IF... you plan to sell any of the plants you collect to defray the cost of your trip, DON'T

IF... you plan to collect for research or study, obtain the agreement (and preferably the collaboration) of competent scientific authorities, such as a government agency or university department, in the host country.

IF... you think 'two or three plants won't be missed', remember someone else may be thinking the same tomorrow, and the next day, and the next...

To the Importer, Private or Commercial

DON'T import wild plants, even if legally permitted, except as a nucleus for propagation and seed-production. And then:

DO check the credentials of suppliers offering wild plants and satisfy yourself they are 'legal'.

DO observe international and national export/import regulations.

To the Nurseryman

DO sell nursery-raised or propagated material only; DON'T advertise or sell unpropagated wild plants under any circumstances, even when legally permitted to do so.

DO try to propagate all rare or documented material and distribute it to recognized Reserve or Reference Collections.

DO keep more than one clone of rare species, even self-fertile ones, for seed production.

DO keep careful records of the origin of all stock, especially any with collector's numbers or locality data, and pass on the information to interested purchasers.

To the Grower/Collector at Home

DO make successful cultivation your prime objective, not the size of your collection or rarity of the plants.

DON'T buy any plant unless you are sure it was nursery-grown; remember that your choice will influence the seller's market.

DO enjoy the satisfaction of raising from seed. Some of the rare or 'difficult' species will test your skill and patience, but reward your success accordingly!

DO record when and from whom you got your plant/seeds, and ask your source for any data: collector's numbers, locality, and so on: all just as vital, to the serious enthusiast, as the name on the label.

DO try to propagate rare and documented material and distribute it to other enthusiasts. It's the old proverb: To keep a plant, give it away!

DO notify one of the addresses on the last page of this leaflet if you suspect a supplier is infringing legal controls.

To the Society and Club

DO endorse the precepts of this Code of Conduct, as a guide for responsible and conscientious behaviour.

DON'T permit wild plants to be advertised for sale in your publications, either openly or by hints.

DO publicize national and international regulations on the export, import and sale of wild plants.

DO sponsor or support national or international measures to protect the habitats of rare and threatened species.

To the Show Committee and Judges

DO include in the schedule some classes for plants raised from seed by the exhibitor.

DON'T permit species protected by CITES Appendix I to be shown in competitive classes, except as seedlings or other propagations raised artificially.

DO make a policy of giving preference to well-grown seedlings over field-collected plants. Check that obvious or suspected 'imports' are properly rooted and established.

LEGAL CONTROLS

The Convention on International Trade in Endangered Species of Fauna and Flora (CITES) gives protection to all cacti and some other succulents. It came into force in 1975 and has been ratified by over 80 countries.

By May 1984, all the countries of North, South and Central America, except Mexico and El Salvador, had ratified CITES. So had the Bahamas, St Lucia, Trinidad & Tobago, and 19 African countries, including South Africa, Zimbabwe, Botswana and Madagascar, all with rich succulent floras, but not yet Ethiopia or Somalia.

One of the main strengths of the Convention is the cooperation it promotes between exporting and importing member states. This helps to reinforce the export regulations of countries with indigenous species under pressure from collectors in other parts of the world.

Some countries both export and import wild plants, notably the USA, which has to control trade in its native species and is also a major importer. Other major importers, such as Britain, West Germany and Japan, are also members of CITES. The European Economic Community (EEC) introduced CITES regulations on 1 January 1984 which apply to all Community countries, including Belgium and the Netherlands which previously did not control the rare plant trade.

There are three categories of protection under CITES, the species in each being listed in Appendices. The succulent species covered are listed in the tables opposite.

The way countries implement CITES may vary according to national legislation. If you intend to import or export any of the species listed, whether or not the plants were collected in the wild, you should check national regulations. Addresses of the national CITES authorities can be obtained from the CITES Secretariat (c/o IUCN, Ave. de Mont Blanc, 1196 Gland, Switzerland) or from conservation organizations. Remember, international trade in wild-collected Appendix I plants is forbidden. A permit or certificate is required to export (and additionally in some countries to import) artificially propagated Appendix I and all Appendix II plants. Failure to comply with CITES may mean confiscation of the plants or criminal proceedings.

In addition to laws implementing CITES, some countries have further legislation protecting plants from trade or collecting. Mexico, though not yet a party to CITES, has regulations covering the collection of all plants from the wild and banning the export of wild-collected cacti. Most countries also have legally designated national parks or other protected areas where the collection of plants or animals is usually forbidden.

The Wildlife Trade Monitoring Unit (WTMU) of IUCN collects information on wildlife trade and monitors the implementation of CITES. WTMU works closely with the CITES Secretariat and coordinates the TRAFFIC* network, which has national offices in West Germany, Japan, the Netherlands, the USA and Australia. These offices welcome information on trade in cacti and succulents which may be threatening the survival of particular species, and on possible infringements of CITES. (*Trade Records Analysis of Fauna & Flora in Commerce.)

Tables of Species protected by CITES

APPENDIX I: Species believed to be endangered with extinction in the wild. International trade in wild plants PROHIBITED.

CACTACEAE

Ancistrocactus tobuschii
Ariocarpus agavoides,
A. scapharostrus, A. trigonus
Aztekium ritteri
Backebergia militaris
Coryphantha minima, C. sneedii,
C. werdermannii
Echinocereus lindsayi
Leuchtenbergia principis
Lobeira macdougallii
Mammillaria pectinifera,
M. plumosa, M. solisioides
Neolloydia erectocentra,
N. mariposensis
Obregonia denegrii
Pediocactus bradyi, P. despainii
P. knowltonii, P. papyracanthus,
P. paradinei, P. peeblesianus,
P. sileri, P. winkleri
Pelecyphora aselliformis,
P. strobiliformis
Sclerocactus glaucus, S. mesae-verdae,
S. pubispinus, S. wrightiae
Strombocactus disciformis
Turbinicarpus (all species)
Wilcoxia schmollii

AGAVACEAE

Agave arizonica,
A. parviflora

APOCYNACEAE

Pachypodium namaquanum

CRASSULACEAE

Dudleya stolonifera,
D. traskiae

FOUQUIERIACEAE

Fouquieria fasciculata,
F. purpusii

LILIACEAE

Aloe albida,
A. pillansii,
A. polyphylla,
A. thorncroftii,
A. vossii
Nolina interrata

APPENDIX II: Species threatened in the wild which may become endangered through trade. International trade controlled and monitored by licensing.

CACTACEAE
All species not covered by Appendix I

AGAVACEAE

Agave victoriae-reginae

APOCYNACEAE

Pachypodium: all species not covered
by Appendix I

ASCLEPIADACEAE

Ceropegia: all species
Frerea indica

DIDIEREACEAE
All species

EUPHORBIACEAE
All succulent species

FOUQUIERIACEAE

Fouquieria columnaris

LILIACEAE

Aloe: all species not covered
by Appendix I

PORTULACACEAE

Anacampseros: all species
Lewisia cotyledon,
L. maguirei,
L. serrata,
L. tweedyi

APPENDIX III: Species threatened in one country which wishes to protect against excessive international trade. No cacti or other succulents are yet listed.

CONSERVATION ACTION

In spite of all the efforts of governments, conservation agencies and lobbies, and in spite of changing attitudes brought about by books and articles, scientific meetings and public debate, the momentum for conservation is still insufficient to diminish the scale and speed of destruction of the world's natural vegetation or to reduce the number of individual species under threat of extinction. More than a decade after the Stockholm Declaration on the Human Environment, one ecosystem alone, the tropical rain forest, is still being destroyed at the rate of 30,000 ha. per day, unknown numbers of plant and animal species are disappearing, and an estimated 25,000 species of flowering plants remain under threat. But there is concerted action, and the tide may eventually turn.

Assessing the problems

Accurate and up-to-date information is essential for planning any conservation action. Past conservation activity has tended to emphasise animals under threat, rather than the plants on which they ultimately depend, but since the International Union for the Conservation of Nature and Natural Resources (IUCN) began to collate data on threatened flowering plants in the late 1960's and set up its Threatened Plants Committee in 1974, many countries have compiled national lists of rare and threatened species. The Conservation Monitoring Centre (CMC) run by IUCN maintains a computerized data-base on threatened species, protected areas and wildlife trade, and, where regional lists do not yet exist, collects information on threatened species from a network of botanists with field experience.

For cacti and succulents, conservation information is still patchy: relatively good for some areas, like the USA, South Africa and the Canary Islands; at the level of informed guesswork for others, like Mexico; and extremely sparse for most of South America and tropical Africa. To promote coordinated effort, IUCN's Species Survival Commission has recently set up a Specialist Group for Cacti and Succulents.

Protected Areas

The best method of species-conservation is effective protection of the natural habitats in which they occur. The number of national parks and other types of protected area has vastly increased in the past decade: over 300 such areas, designated for nature conservation, are listed in the IUCN Directory of Neotropical Protected Areas for Central and South America and the Caribbean region alone.

Usually, national parks and reserves are established to preserve rare animals, scenic areas or examples of particular ecosystems, but in the USA two have been set up specifically to protect cacti: Organ Pipe and Saguaro National Monuments, both in Arizona. In South Africa, the Hester Malan Reserve, Darling Wild Flower Reserve and Nortier Reserve have all been established to protect plants.

Nevertheless, we must not be complacent. Few protected areas have adequate resources for management and effective policing, and problems of land-tenure, development projects, poachers, collectors or just the tramping feet of sight-seers, can all too often nullify the value of legal protection.

Reserve Collections

Cultivation in a botanical collection can be a life-line for species whose wild habitat is destroyed or under threat and where conservation measures in the field are impracticable or ineffective. Propagation of cultivated material can also take the pressure off wild populations threatened by over-collecting.

In 1979, the Botanic Gardens Conservation Coordinating Body was set up. Run by IUCN, it now has 125 members in 30 countries (May 1984). Lists of threatened plants compiled by the Conservation Monitoring Centre are circulated to members to establish where such plants are held in cultivation and which species are lacking. Lists circulated have included: threatened and insufficiently-known Mexican endemic cacti; succulent Euphorbias and Aloes of tropical and southern Africa; and succulents of Madagascar. Of the 328 taxa on the Madagascan list, 73% were located in 42 gardens in the first year.

IOS published a Register of Succulent Plant Collections in 1980. Six of special importance, at Zürich, Heidelberg, Hamburg, Linz, Worcester/South Africa (Karoo Botanic Garden) and San Marino/USA (Huntington Botanical Gardens) are designated IOS-affiliated Reserve Collections.

Private collectors specializing in particular groups and maintaining well-documented collections have an important role in growing, propagating and disseminating material of threatened species. Attempts to register such collectors and promote interchange of material have been made, and may be expected to develop in years to come.

FURTHER READING

Allen, R. (1980). How to save the world. Kogan Page, London. A popular book on international conservation.

Lucas, G.L. & Synge, H. (1978). The IUCN Plant Red Data Book. IUCN, Gland. Includes data sheets on 19 species of cacti and other succulents.

Miller, K.R., McNeely, J.A. & Harrison, J. (1982). IUCN Directory of Neotropical Protected Areas. Tycooly Int. Publ. Ltd, Dublin.

Prance, G.T. & Elias, T.S. (1977). Extinction is forever. Proc. Symp. New York Bot. Gard. May 1976. New York Bot. Garden. Information on plant conservation throughout the Americas, including a paper by L. Benson on 'Preservation of cacti and management of the ecosystem'.

Synge, H. (ed.) (1981). The biological aspects of rare plant conservation. J. Wiley, Chichester. Papers from a conference at Cambridge, including a bibliography of Red Data Books and threatened plant lists.

Synge, H. & Townsend, H. (eds.) (1979). Survival or extinction. Proc. Conf. Roy. Bot. Gard. Kew, Sept. 1978. Bentham-Moxon Trust, Kew. Proceedings of a conference on the practical role of botanic gardens in conservation.

USEFUL ADDRESSES

Information Centres

Conservation Monitoring Centre
The Herbarium
Royal Botanic Gardens Kew
Richmond
Surrey TW9 3AE England

CITES Secretariat
c/o IUCN
Avenue de Mont Blanc
CH-1196 Gland
Switzerland

Wildlife Trade Monitoring Unit
219(c) Huntingdon Road
Cambridge CB5 0DL
England

TRAFFIC (Nederland)
Muur 10
Uithoorn
Netherlands

TRAFFIC (Germany)
Sophienstrasse 44
D-6000 Frankfurt-am-Main
West Germany

TRAFFIC (Japan)
6th floor #39 Mori Bldg
2-4-5 Azabudai, Minato-ku
Tokyo 106 Japan

TRAFFIC (Australia)
c/o Fund for Animals
P.O. Box 371
Manly 2095 NSW
Australia

TRAFFIC (USA)
WWF US
1601 Connecticut Avenue NW
Washington DC 20009
USA

IUCN Species Survival Commission Specialist Group

IUCN-SSC Cacti & Succulents Group
c/o The Herbarium
Royal Botanic Gardens Kew
Richmond
Surrey TW9 3AE England

Membership Organizations

The World Wildlife Fund has 24 national organizations. Addresses and details of their plant conservation activities can be obtained from:

WWF International
Avenue de Mont Blanc
CH-1196 Gland
Switzerland

Other membership organizations include:

Fauna & Flora Preservation Society
c/o Zoological Society of London
Regent's Park
London NW1 England

Natural Resources Defense Council Inc.
1725 1st Street NW
Suite 600
Washington DC 20006 USA

Groups set up to discourage trade in wild-collected succulents:

Aktiegroep voor de Bescherming
van Cactussen (ABC)
Sparrenstraat 5
2930 Hombeek
Belgium

Werkgroep Succulenten Bescherming (WSB)
Bakkersgilde 23
3994 BC Houten
Netherlands

Contract Paper No. 13

Technologies to Maintain Tree Germplasm Diversity

Frank T. Bonner
U.S. Forest Service

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Office of Technology Assessment
U.S. Congress

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TECHNOLOGIES TO MAINTAIN TREE GERMPLASM DIVERSITY

Draft Paper for Office of Technology Assessment

F. T. Bonner
USDA, Forest Service
Southern Forest Experiment Station
Starkville, Mississippi 39759

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ABSTRACT

Conservation of plant genetic resources is a critical world-wide need. Activities in this area for forest tree species have lagged behind those of agricultural species, but there is much more awareness of the forestry problem at the present. There is considerable international effort at conservation of forest germplasm, moderately supported and coordinated by FAO and its Panel of Experts on Forest Gene Resources.

Technologies available include:

A. In-situ conservation - best for saving entire ecosystems with large gene pools; good for tropical hardwoods.

B. Ex-situ conservation - widely used for fast-growing plantation species; well-suited to international cooperative efforts because seeds can be shipped to available sites.

C. Conventional seed storage - supporting role only for tree germplasm, since regeneration of seed supplies requires very long periods; relatively cheap; genetic damage during storage is unknown.

D. Cryogenic storage - storage in liquid nitrogen at -196°C; potentially very useful, but still in research stage.

E. Storage of pollen - little potential, except as micropropagation tissue.

F. Micropopagation tissues - long-term storage of suspension cultures is intriguing, but we are in the early research stages; may help most with tropical recalcitrant species which are endangered.

Recommended action to conserve tree germplasm includes:

1. Increase efforts for in-situ conservation, especially in moist tropical forests.

2. Assist in international efforts for more ex-situ conservation plantings.

3. Continue research on conventional seed storage of true orthodox and sub-orthodox seeds. Increase efforts with these species in cryogenic storage.

4. Increase research efforts to conserve species with recalcitrant seeds. High-priority areas are reproductive biology, conventional seed storage, and micropropagation techniques.

Specific suggestions for Congressional actions are also presented.

TECHNOLOGIES TO MAINTAIN TREE GERMPLASM DIVERSITY

I. INTRODUCTION

Conservation of plant genetic resources is a critical world-wide need. Successful conservation can ensure the genetic diversity needed to meet future demands for food and fiber. Justifications for maintaining genetic diversity in agricultural species are easily made, and collections of wheat, rice, maize, etc. number in the tens of thousands of varieties (Timothy and Goddman 1979).

Conservation of forest genetic resources has lagged behind that of agricultural species, and understandly so. Widespread screening of natural forest populations in the U.S. to select superior phenotypes of a few valuable species for tree improvement programs became common in the 1950's. Major international efforts originated in the late 1960's with guidance and support of FAO and several national institutions. The past fifteen years have seen considerable strides in this direction, stimulated by three factors: (1) The maturity of tree improvement programs has demonstrated how much economic benefit is possible by selecting the best genetic resources; (2) The trend of environmental "awareness" has made people everywhere recognize the need to preserve the natural gene pools; and (3) The prospect of tropical and sub-tropical deforestation on a massive scale has been widely publicized.

Recent estimates have listed about 300 tree species or particular provenances which are endangered (FAO 1984). The official list of endangered and threatened plants in the United States includes only three trees (U.S. Dept. of the Interior 1983), but this document does not include endangered provenances.

Participating Organizations

Current international efforts to conserve forest gene resources are primarily those of governmental bodies or institutions. The most active organizations are: CSIRO Division of Forest Research (Australia), DANIDA Forest Seed Centre (Denmark), Commonwealth Forestry Institute (United Kingdom), and Centre Technique Forestier Tropical (France). The international activities of these organizations, and many others, are supported and coordinated by the Forest Resources Division of FAO. The Division is aided in the planning of these activities by the Panel of Experts on Forest Gene Resources. This Panel is composed of fifteen tree or seed improvement specialist. While the United States has been represented in the past, we have no current member on the Panel.

FAO in recent years has made available around $90,000 per year for seed procurement of valuable species (FAO 1984); the National Tree Seed Laboratory of the U.S. Forest Service at Macon, Georgia has been receiving about $2,000 of this amount. FAO has also helped pay for establishment of *ex-situ* conservation stands in several tropical countries.

FAO also supports the International Board for Plant Genetic Resources (IBPGR), an autonomous, international scientific organization of members from 13 countries, by providing a Secretariat. The function of IBPGR is to promote an international network of genetic resources centers to further the collection, conservation, documentation, evaluation, and use of plant germplasm to improve living conditions worldwide. IBPGR considers forest tree resources also, and they are currently sponsoring an inventory of all tree germplasm conservation activities in the world. Results of this study, headed by Dr. A. G. Gordon from United Kingdom, are not yet available.

Many governmental agencies are active in forest gene resource conservation within their own national boundaries. These programs are designed to meet national goals, as would be expected, and concentrate on commercially valuable species.

In parts of the world where private ownership of forests is widespread, forest industries have made significant contributions to preserving gene resources. This is especially true in Central and South America, where an outstanding cooperative effort is headed by CAMCORE, Central America and Mexico Coniferous Resources Cooperative. This organization, composed of both governmental bodies and private industry, has been concentrating on provenance collection of pines. They have established provenance and progeny tests and preservation plantings on lands of the membership (ISTF 1983).

Private, noncommercial organizations play a minor role in forest gene resource conservation. In the United States the Nature Conservancy is the most prominent group. The "natural preserves" which this organization acquires are not solely intended for gene conservation, but they serve that purpose also. Other examples of this type of conservation can be found around the world, but outside of wildlife refuges, their impact is not great.

The preponderance of gene resource conservation worldwide is directed toward commercially valuable tree species. Noncommercial species are primarily conserved _in-situ_ through their presence in natural ecosystem preserves, parks, and wildlife refuges. Conservation by private noncommercial organizations is more likely to consider noncommercial species than activities by governments.

In-situ Conservation

The extent of _in-situ_ conservation worldwide is very difficult to estimate. In the United States forest ecosystems are protected in our National Park System (15.5 million acres), the National Forest System Wilderness Areas (over 25 million acres)(USFS 1984), various state parks, and private or organization preserves. While little of this area was set aside specifically for gene conservation, it can serve that purpose. Similar, but smaller areas have been preserved in other countries. Most are in temperate zones, however, and too little has been set aside in moist or dry tropical areas to date. The FAO Panel of Experts encourages *in-situ* preservation, and FAO has funded the establishment of two small areas for this purpose in Zambia (FAO 1981). There is increasing evidence, however, that tropical countries recognize the importance of forest gene conservation, and more and more *in-situ* preserves are being established.

Additional germplasm conservation is maintained through protection of small areas which contain endangered species. An example in the United States is the protection of a small number of Virginia round-leaf birch (*Betula uber*) trees by the U.S. Forest Service in Virginia. Most conservation of rare and endangered species is *ex-situ* in gardens and arboreta.

Ex-situ Conservation

Efforts in this area are concentrated on economically valuable fast-growing plantation species. There is little *ex-situ* conservation of noncommercial species. The over 15,000 acres of established seed orchards and clone banks in the United States (U.S. Forest Service 1982) provide extensive *ex-situ* conservation of some of the better gene complexes in our most valuable species. Almost as valuable are the thousands of hectares of provenance and progeny tests and commercial plantations of known origin. Similar operations exist in most developed countries.

The *ex-situ* conservation programs in tropical countries are, for the most part, smaller and more recent. Projects coordinated by and partially financed by FAO/UNEP have established over 400 ha of conservation/selection stands in 6 tropical countries, using 11 provenances of 4 different species (FAO 1981). Many tropical countries are now establishing provenance trials for fast-growing plantation species, and a large proportion of these plantings will probably evolve to seedling seed orchard status or what Willan (1984) calls "provenance conservation stands." In this way, the extent of *ex-situ* conservation will be greatly expanded.

Seed Storage

Current efforts at forest tree germplasm conservation include seed storage at several international and national centers (Table 1).

Table 1. - Some major international seed storage centers.

Center	Country	Approximate Size of Collection Species	 Sources	Reference
United States Forest Tree Seed Center	U.S.	67	197	Karrfalt (1985)
National Seed Storage Laboratory	U.S.	18	41	Bass (1985)
Petawawa National Forestry Institute	Canada	118	2130	Janas (1984)
DANIDA Forest Seed Centre	Denmark	46	187	Anonymous (1985)
CSIRO Tree Seed Centre	Australia	900	4000	Turnbull and Doran (1985)
CFI, Oxford	U.K.	*	*	
Banco Latinoamericano de Semillas Forestales	Costa Rica	153	308	Anonymous (1983)
Banco de Semillas, COHDEFOR	Honduras	*	*	

* Not available

In addition, many countries have national seed storage facilities which serve their domestic needs. It is difficult to say how much of this seed storage is for long-term preservation of germplasm; it is primarily designed for short-term storage to establish provenance trials and ex-situ conservation stands.

II. TECHNOLOGIES TO MAINTAIN TREE GERMPLASM

A. *In-situ* Conservation

Long-lived perennial plants, in contrast to annual crop species, offer a distinct advantage in germplasm conservation through "storage on the stump." *In-situ* storage of entire ecosystems is the ideal method of germplasm conservation, which best can ensure genetic diversity. Advantages of this method are:

1. Entire ecosystems with large gene pools can be saved, not just selected gene complexes.
2. Undesirable phenotypes, which may contain gene groups of undiscovered value, are conserved also.
3. Species which are difficult to artificially regenerate, such as tropical Dipterocarps or other species with recalcitrant seeds, can be conserved best *in-situ*.
4. In moist tropical hardwood forest, many species can be conserved in a relatively small area. This does not negate the need for large areas, however, to insure a wide range of characteristics.
5. Other types of forest preserves (national or state parks, wildlife refuges, etc.) can be utilized for *in-situ* conservation, thus avoiding large initial land cost.

Some disadvantages are:

1. Large amounts of land are required, thus making this an expensive type of conservation.
2. Conservation *in-situ* may be relegated to remote or marginal sites only, thus missing many of the better gene groups.
3. In instances of *in-situ* conservation in wilderness areas, protection against fire, insects, and diseases may be poor.

4. Political pressures to convert the land to other uses may prevail, thus losing the material.
5. Inclusion of all important geographic sources of a species is usually impossible because too many separate areas will be required.
6. Geographic isolation can make maintenance and seed collection difficult.
7. Adequate botanical inventories are often not available for choosing the sites for *in-situ* conservation.
8. Some level of management is needed, or natural succession will eventually alter the gene pool.

Because of size, expenses, and land-use considerations, *in-situ* conservation is usually a governmental undertaking. Involvement by the private sector will remain minimal in most parts of the world. Increasing pressures on forest lands may eventually force all *in-situ* conservation to be combined with other uses: zoos, parks, watershed forests, wilderness areas, etc. In developed countries this approach can work very well. In developing countries, land use pressures will be much greater, and *in-situ* conservation may be limited to only small preserves. Since up to 100 species may occur on only 0.4 ha in moist tropical hardwood forest (FAO 1984), important germplasm conservation is still possible.

In-situ conservation can make a significant contribution to maintenance of genetic diversity for those species which are not widely established in plantations. The most significant group of species to which this applies is the moist tropical hardwoods. Population pressures and economic problems of the countries involved (e.g. the need for foreign exchange) make these ecosystems the most difficult to preserve by *in-situ* means. Tropical deforestation continues, and although the rates here leveled off in Southeast Asia (Palmberg 1984), even the recent conservative estimate of 7.1 million ha per year (Sedjo and Clawson 1983) illustrates that time is running out for large amounts of in-situ conservation in the moist tropics.

Major technical constraints on in-situ conservation are a lack of good botanical inventories of prospective sites and a lack of good protection technology (fire, insects, etc.). Non-technical constraints include high costs (if land must be purchased), land-use conflicts (usually agriculture or ranching), and social problems when indigenous proples must be displaced. These last two constraints can be minimized by governments through careful planning.

B. Ex-situ Conservation

Where in-situ conservation is not practical or possible, ex-situ conservation is most widely used. This type of conservation is applicable to economically valuable, fast-growing plantation species; species likely to become extinct due to vanishing natural stands; pioneer species which grow in simple plant communities; and multi-purpose species important in agroforestry. It is most widely used in the first case, that of valuable plantation species. Some advantages to ex-situ conservation are:

1. Selected phenotypes can be preserved, even if their natural stands are all destroyed.
2. Material from all geographic races can be used, thus ensuring probable conservation of all important gene groups of the species.
3. Different site conditions can be utilized for conservation, including sites outside of the natural ranges.
4. If the species can be propagated vegetatively, this can be a cheap way to conserve genetic material (Zobel and Talbert 1984).
5. Plantations can be established in locations suitable for easy access for maintenance and seed collection.

6. Significant plantings can be made on sites of only 10 ha (Willan 1984).
7. Any provenance test, progeny test, or plantation of documented origin can be utilized for ex-situ conservation.
8. It is very appropriate for multi-purpose species.

There are disadvantages as well:

1. It is difficult to establish some species in plantation (i.e. shade-tolerant tropical hardwoods with recalcitrant seeds).
2. The genetic base of the conserved material is usually smaller than that in in-situ conservation.
3. Because of the expense of establishment and plantation maintenance, usually only economically important species are conserved by this method.
4. Some segments of society object to the emphasis on plantation forestry, especially if it leads to "monoculture forestry."
5. Planting sites available for ex-situ conservation may not be suitable for the species planted there, a fact which may become apparent only after plantation failure in later years.

The increasing trials of exotic species in tropical countries and the increasing international cooperation under FAO and other organizations have created a climate in which ex-situ conservation is emphasized over other means. The disappearance of many natural stands from logging, agricultural clearing, etc. also contributes to this climate of cooperation. Ex-situ conservation will expand over the coming years.

Conservation by ex-situ means is also largely a governmental operation in most countries, but the private sector may be involved also. In the United States, tree improvement programs of industry create large amounts of ex-situ gene conservation in seed orchards, clone banks, seed production areas, progeny and provenance, and plantations of known origin. Tree improvement cooperatives in the South maintain good documentation of these areas and provide a continuity which might not always be present in industry programs.

The major constraint on the value of ex-situ conservation is the narrow genetic base in many programs. To adequately preserve a high degree of genetic diversity, collections should be made from throughout the range of a species. Estimates of how many individuals to save from each geographic race range from 50 to 400 (Zobel and Talbert 1984); a figure mid-way in this range seems reasonable. For species with large natural ranges, such an operation could be quite expensive, and few ex-situ conservation programs go that far. The ideal situation is to first study natural variation throughout the range, then determine how many geographic races should be saved. This information is available for just a few species (e.g. loblolly pine, slash pine, Scotch pine, Norway spruce, etc.), and it is impractical to think that comparable data will soon be available for the hundreds of other important tree species in the world. This information will come slowly for a few species at a time.

It is best to establish ex-situ plantings of 10 ha each on several different sites. Genotype-environment interactions are possible, yet unknown for many species, so valuable information can be gained by scattering the plantings (Willan 1984). Ex-situ gene conservation is most applicable to shade-intolerant fast-growing plantation species. Species groups with recalcitrant seeds are not favored by this method, because shipment of seeds and plantation establishment are so difficult.

For social, environmental, and sometimes valid scientific reasons, "monoculture forestry" does not have a good image with the general public. Ex-situ gene conservation programs should avoid this image by including as many species as possible, including multi-purpose trees.

Major technical constraints on ex-situ conservation are: (1) inadequate supplies of seeds or seedlings of all important sources, (2) lack of seed technology for tropical recalcitrant species, (3) difficulty of plantation establishment in stressful environments, (4) possible lack of essencial microbiological associates from natural sites, and (5) lack of adequate information management related to seed source and plantation performance (poor record keeping).

There are non-technical constraints as well: (1) large cost of plantation establishment, (2) inadequate protection from livestock and people in some regions, and (3) a social resistance to plantation forestry, especially monocultures or exotics. Increasing the use of indigenous and multi-purpose species in *ex-situ* conservation will help in this last constraint. There is a growing awareness that multi-purpose species have been somewhat neglected in reforestation planning. In many locations acceptance by the local population is essential to the success of *ex-situ* plantings; acceptance may be facilitated by increasing the component of indigenous, multi-purpose species.

C. Conventional Seed Storage

Conventional seed storage refers to storage of intact, unaltered seeds by control of the storage environment. This technique is the mainstay of germplasm conservation for annual species of agricultural importance. When viability of stored lots decreases 5 to 10 percent, the normal procedure is to regenerate the collection in the field (FAO 1984). Such a procedure for tree species is impractical because of the long vegetative period before seeds are produced (up to 20 or more years). Conventional seed storage, therefore, is primarily a supplemental method for germplasm conservation for trees *at this time*. Its greatest value is perhaps in supporting establishment of *ex-situ* plantations for conservation.

Storage of seed is indispensable to plantation forestry, however, and the practice should not be dismissed too readily as a basic tool in maintaining genetic diversity. There are several advantages:

1. Seeds of some valuable species can survive long-term storage. "Long-term" is defined as spanning a period of time longer than one rotation (FAO 1984).
2. Good storage facilities are available in most of the world now, and they are used extensively for tree seed storage for various regeneration purposes.
3. It is a relatively cheap method of conserving a broad range of material.
4. Large land areas are not tied up in conservation.
5. Seed storage facilitates the international exchange of genetic material.
6. There are no political or social constraints.

Disadvantages of this technology include:

1. As far as we know, seeds of most important tree species cannot adequately survive long-term storage.
2. Seeds of most tropical hardwoods cannot survive a year of conventional seed storage.
3. Some genetic damage may occur during seed storage, as chromosome breakage is known to occur.
4. In some remote areas, especially in the tropics, reliable storage facilities may not be available.
5. Too much time is required to regenerate tree seed supplies for continued storage.

Plant species have traditionally been divided into two groups for seed storage purposes: (1) orthodox, and (2) recalcitrant (Roberts 1973). Division into four groups seems more appropriate for this assessment: (1) true orthodox, (2) sub-orthodox, (3) temperate recalcitrant, and (4) tropical recalcitrant.

True orthodox seeds can be stored for relatively long periods at subfreezing temperatures, if their moisture contents are reduced to the 6 to 10 percent range. For short-term storage of 5 years or less, temperatures of 0 to 5°C are satisfactory; for longer storage - 15°C is commonly used (Bonner 1981). Most species of the economically valuable tree genera of the temperate zone are classified as orthodox: *Pinus*, *Picea*, *Larix*, *Abies*, *Tsuga*, *Pseudotsuga*, *Alnus*, *Fraxinus*, *Liriodendron*, *Platanus*, *Liquidambar*, *Betula*, *Prunus*, etc. True orthodox genera of great economic importance in the tropics include: *Acacia* and other Leguminosae, *Eucalyptus*, *Casuarina*, and *Gmelina*.

Good data on long-term storage of true orthodox seeds is lacking. Elliason and Heit (1973) reported 86 percent germination *Pinus resinosa* samples stored for 42 years. Barnett and Vozzo (1985) found germination of *P. elliottii* was still 66 percent after 50 years of storage at 4°C, but there was evidence of loss of vigor. Both studies lacked the good environmental controls available today, and early germination tests may not have been under the best of conditions. It is possible that much longer storage is possible.

Sub-orthodox species are those which can be stored under the same conditions as true orthodox seeds, but for shorter periods. Sub-orthodox species include seeds with very high lipid contents (*Juglans nigra*, some *Carya* species) and small seeds with thin seed coats (*Populus*, *Salix*).

There are some tree seeds which were once labeled as recalcitrant, but are now considered as sub-orthodox in storage behavior. Carefully controlled drying can be used to bring these seeds down to low moisture contents, thus extending storage life. Some examples are *Fagus* (Bonnet-Masimbert and Muller 1975; Suszka 1975) and *Citrus* (King *et al* 1981).

If more were known about the storage potential of all tree species, the sub-orthodox group would undoubtedly expand at the expense of true orthodox species.

Both types of recalcitrant seeds can be stored only for short periods of time, and there is tremendous variation among genera and species within genera. The major distinction of recalcitrant seeds is that they cannot be dried to moisture contents below relatively high values. These critical values range from 20 to 50 percent of fresh weight, depending on the species.

Temperate recalcitrant species, such as Quercus and Aesculus are cold-tolerant; they can be stored near freezing. North American species do best at 0 to 2° (Bonner 1973), while some European species can tolerate -3°C (Suszka and Tylkowski 1980; 1982). Because of their high moisture contents, these seeds are very active metabolically. Even at low temperatures germination is common during storage. Insects and fungi can also be very active in seeds at these high moisture contents.

By maintaining high seed moisture contents (35 to 40 percent) and a certain amount of gas exchange seeds of some Quercus species can be stored for 3 to 5 years at or near freezing with only moderate losses of viability (Bonner 1973, Suszka and Tylkowski 1980; 1982). This is the best reported success for any type of recalcitrant seed but it is clearly not good enough to meet germplasm conservation goals.

Tropical recalcitrant species have the same moisture and gas-exchange requirements as the temperate recalcitrant species, but they are sensitive to low temperatures. Even short periods below about 10°C will cause loss of viability (Bonner 1981; Yap 1984). Included in this group are many Shorea species (Yap 1984), cacao (King and Roberts 1979), and Hopea species (Tamari et al 1984).

Genetic changes during conventional seed storage are possible, and there have been reports of chromosome damage in some tree species during storage (Bonner 1984). There is still no evidence that these chromosome aberrations cause genetic damage which is transmitted to the next generation, however, and research is badly needed on this question. Genetic damage in storage would form a serious constraint to use of this technology. Changes in genetic makeup of heterogeneous seed stock (usual for tree seeds) will also occur during storage, as the death of some seeds may remove some gene groups from the pool. We have absolutely no data on this for tree species, but Roos (1983) has demonstrated the effect in mixed bean populations. The importance of this problem in tree species should be less, though, because of the wider genetic base of most collections.

The technology for effective conventional storage of seeds of both types of orthodox species is simple and is available worldwide. Were it not for the long times required for regeneration of seed supplies, it would be a very cost-effective method of germplasm conservation for trees. The inability to store any recalcitrant seeds over a long period is a major constraint with these species. Seed storage will likely play a complementary role in conservation (FAO 1984) as follows: (a) temporary measure of conservation until ex-situ stands are established, (b) a safety measure for limited numbers of seedlots as insurance against disaster losses. It should be pointed out, however, that there is a potential for much greater use of conventional seed storage with valuable true orthodox species. Research is needed to determine the potential.

Non-technical constraints on conventional seed storage are a lack of organized seed acquisition schemes in many countries and a lack of good storage facilities in others.

D. Cryogenic Storage

Preservation of biological materials in liquid nitrogen (LN_2) at -196°C has been in use for many years for the storage of animal semen for breeding purposes. At these temperatures genetic or developmental changes should not occur over a period of at least decades (Grout *et al* 1983). Samples of true orthodox seeds, including some firs and pines of the United States, have been stored for up to 6 months in LN_2 without adverse effects (Stanwood and Roos 1979). This technology is so new to seed storage that the time limits of storage of true orthodox seeds have not yet been determined. Unicellular plant material has been stored for at least 10 years (Stanwood and Bass 1978).

Cryogenic storage of recalcitrant seeds is another matter. Since these seeds cannot be dried to 10 perchnt or below moisture contents, different steps are necessary. Chemical cryoprotectants such as dimethyl sulfoxide (DMSO), which prevent freezing damage in the moist tissue are one possibility. A more recent finding has been that excised embryos of the tropical recalcitrant oil palm (*Elaesis guinensis*) seed behaved in an orthodox manner when dried to 10.4 percent and stored in LN_2 for 8 months (Grout *et al* 1983). Germplasm conservation by means of excised embryo storage does not appear, on the surface, to be practical, but its success in one instance does suggest that possibilities exist for recalcitrant seeds of high economica value through innovative techniques.

While cryogenic storage suggests only limited application for small supplies of seeds, cost estimates by Stanwood and Bass (1978) show that cryogenic storage compares favorably with conventional seed storage. Size is the big factor. For small seeds (clover, carrot, *Eucalyptus*) $0.03 per sample-year was estimated (in 1978); for larger seeds (soybeans, *Abies*) costs estimates were $1.26 per sample-year.

Some advantages of cryogenic storage are:

1. It can apparently extend storage life of true orthodox species far beyond that possible in conventional storage.
2. Genetic damage may be much less than what occurs in conventional storage.
3. Research suggests that much improvement is possible.

Disadvantages include:

1. Special equipment is required, which is not readily found in forestry facilities.
2. It is costly for large seeds.
3. Recalcitrant seeds (both types) cannot be stored cryogenically with current technology.

Cryogenic storage at its current level of technology offers great promise for long-term storage of true orthodox and sub-orthodox seeds. Current cost and facility restrictions might limit this to only the most valuable material. There is also potential for application to recalcitrant species, but much more research and development will be required.

There appears to be no social, environmental, or political constraints to development of cryogenic storage of seeds. All current application is at the research phase. Additional research facilities and funding may be required from government sources, but these are the only constraints. Private sector involvement is unlikely because of the long-term nature of this work.

E. Storage of Pollen

Germplasm conservation by storage of pollen has only three advantages.

1. Low storage space requirements.
2. Pollen is haploid tissue, which presents some advantage in breeding programs.
3. Pollen can be easily shipped for international exchange.

There is one major disadvantage:

1. Storage life is generally shorter than that of seeds (Wang 1975).

With modern freeze-drying techniques, pollen can be stored at very low moisture contents at subfreezing temperatures. Pollen of some Canadian conifers was stored for up to 13 years at -18°C and very low moisture content, but not all lots produced successful pollinations (Wang 1975). Pollen storage does not appear to offer much as a primary technology for germplasm conservation. It is a very valuable part of seed orchard management and breeding programs, however, and in that manner it will play a large role in *ex-situ* conservation. Pollen tissue can also be used in micropropagation, as discussed in the next section.

F. Micropropagation Tissue

Considerable research and development is currently taking place in the fields of shoot tip culture, callus culture, and cell culture in forestry (McKeand and Weir 1984; Thompson 1984). While the major objective is mass-production of superior clonal lines, some aspects of this technology may have application to germplasm conservation. If endangered recalcitrant species cannot be conserved by *in-situ* or *ex-situ* means, then some material might be saved through these techniques. Somatic embryogenesis has already been demonstrated in the laboratory with cell cultures of several woody plants, including tropical recalcitrant species such as *Coffea canephora*, and *Theobromo cacao* (Thompson 1984).

More intriguing is the possibility of storing shoot tip or suspension cultures cryogenically for long periods. As early as 1974 Sugawara and Sakai (1974) reported survival of suspension cultures of *Acer pseudoplantus* cells after rapid cooling to -195°C for 15 to 20 minutes. The primary advantages of this technique over cryogenic storage of intact seeds (or embryos) would be its application with genetically altered cells or haploid tissue of valuable tree species. In the latter case, the use of pollen cell culture also has possibilities. Another advantage would be the easier movement of such material across international boundaries as compared to seeds, since quarantine restrictions would not normally apply to this sterile material.

Micropropagation is currently operational in some parts of the horticulture industry, but we are still in the experimental stages in forestry. The technical constraints are by far the most important in this technology. Private industry will play a large role in developing micropropagation, but government research programs must take the lead in application for germplasm conservation.

There are possible environmental and social constraints which may arise from organizations and individuals opposed to all forms of genetic engineering and associated technologies. These problems must be solved on a larger scale for all plant and animal biological research, however, and particular problems related to tree germplasm will be minor.

G. Current Application

In the United States most of the effort for tree germplasm conservation has been in *ex-situ* conservation of selected material in tree improvement programs. Large-scale *in-situ* conservation has occurred through the establishment of national parks, wilderness areas, etc., but the primary purpose of these areas is not germplasm conservation. Conventional seed storage currently plays only a minor role in tree germplasm conservation in the United States. It is primary used as a support technology for *ex-situ* conservation. All other technologies are in the research stage only for trees.

In other developed countries of the temperate zones, efforts are similar to those of the United States. The Canadian situation is very much the same. In Europe, *ex-situ* conservation may play a larger role, because of their long use of exotic species. Conventional seed storage remains a support technology where true orthodox species predominate, as in temperate zone developed countries.

In tropical countries, the most widely used technology at present is *in-situ* conservation, although the area in reserves is still far from adequate. *Ex-situ* conservation is increasing, however, with expanded international exchange of seed. Much of this increase is with fast-growing exotics and not with indigenous species. Major reasons for this are that: (1) these exotics have orthodox seeds which are easy to collect, ship, and store, and (2) they are available from organizations such as CSIRO, FAO, etc. It is much easier to purchase these seeds than it is to collect and store seeds of indigenous species for which proper seed technology is not available. Thus, few species from the moist tropics, which have recalcitrant seeds, are included in *ex-situ* conservation plantings.

III. IMPROVEMENT OF TECHNOLOGIES

A. *In-situ* Conservation

This method of conservation is most critical for tropical and sub-tropical hardwoods, where land-use competition from agriculture is rapidly decreasing the opportunities to set aside ecosystem preserves. The key to improvement of *in-situ* conservation is international efforts through FAO or private organizations such as the World Wildlife Fund. National parks and wildlife refuges can also serve as *in-situ* conservation of plant germplasm. While this may be occurring *de facto* at this time, it should be formalized through planned cooperation.

International organizations and developed countries should increase assistance to tropical countries, where conservation of indigenous species is most crucial. The first aid should come in inventories of what species exist and the extent of their distribution. In many tropical areas, there are woody plants which have not been described and named. While plant exploration on the ground is required, satellite mapping of vegetation can be very helpful, and its use should be expanded. There is a growing awareness of tropical countries that some in-situ conservation of ecosystems is desirable, and helping to provide accurate forest inventory data to these governments could have a favorable influence on which sites to conserve.

In the United States, ample natural stands of most species occur for in-situ preserves. There is a need to systematically document these areas and formally designate some for germplasm conservation.

Increasing in-situ conservation presents no pressing needs for research. The technical knowledge to preserve natural ecosystems is on hand.

B. Ex-situ Conservation

Germplasm conservation by this means is becoming increasingly popular, because ex-situ stands also provide accessible material for their selection and breeding and also for evaluation of exotic species. Host countries or organizations are more interested in genotypes of local superiority, while conservation of all possible genes is more important to international institutions. This is a potential conflict which could present problems of access to the material by foreign researchers, and some sort of international agreements are needed to prevent the situation.

Other governmental action needed is a liberalization of import/export restrictions on repfoductive materials where international provenance trials and establishment of ex-situ conservation stands are involved. International movement of short-lived recalcitrant seeds is often impossible. International agreements are needed to allow freer movement of seeds, but still permit adequate seed health precautions.

Emphasis should be increased on endangered species and their propagation. More seed collections should be made from all possible geographic sources. This material would then be available for establishing ex-situ conservation stands and clone banks, or it could be stored in seed banks for later distribution for this purpose. But early action is desirable before too many sources are lost.

Establishment of ex-situ conservation stands should be expanded to include more multi-purpose tree species (those often identified as important for agroforestry or social forestry). Continued emphasis on major timber species only can have a negative influence on governments of developing countries. Including more conservation of multi-purpose species can alter the image of exploitation of tropical resources for the benefit of developed countries only that sometimes occurs.

Increased emphasis is also needed on species for arid-zone utilization. The FAO program has expanded greatly in recent years in this direction (FAO 1984), but even more should be done. Most efforts have been centered on saving indigenous species in arid countries. There should also be additional exploration, seed collection, and evaluation of species and sources which have not been emphasized in the past; one example would be the arid and semi-arid zones of southwestern United States.

Finally, a great research effort is needed to study the reproductive biology of species with tropical recalcitrant seeds. This feature prevents large-scale ex-situ conservation of many species, and unless answers are found soon, some gene resources will be lost. The research should also explore vegetative propagation, which could avoid regeneration difficulties of the recalcitrant seeds. There is no significant research in the United States on this topic. Outstanding efforts may be found in the Kew Gardens research unit (U.K.); Forest Research Institute, Kepong, Malaysia (S.K. Yap); and the Tropical Agriculture Research Center, Japan (C. Tamari).

Research is also needed on how to collect and handle tropical recalcitrant seeds, grow the seedlings, and successfully outplant them. There is no significant research in the United States on this topic. Research in tropical countries is focused on local species and conditions only; there are no recognized "centers of excellence." This type of research must be carried out on-site; it cannot be done in research institutions of developed countries.

C. Conventional Seed Storage

For the most part, conventional seed storage will continue to support and supplement gene conservation through *ex-situ* plantings. There are several aspects of seed storage, however, through which improved technology could greatly expand the role of seed storage in gene resource conservation. One aspect is the absolute storage potential for true orthodox and sub-orthodox tree seeds. There are at present no good data on the length of storage possible under well-controlled conditions of these seeds. It is possible that some true orthodox species, such as members of the Leguminosae, may be safe for long-term storage in conventional seed storage conditions. Research with a wide variety of species should begin immediately. Current work on this problem is underway at the Forestry Sciences Laboratory (FS) Starkville, Mississippi, Petawawa National Forestry Institute, Canada, CSIRO Seed Centre, Canberra, Australia, and the University of Reading, U.K.

Concurrent with the storage research, the potential for genetic changes during long-term storage should be investigated. This work should range from the importance of chromosome aberrations in stored seeds to the impact of genetic drift in heterogeneous populations as a result of certain portions of the populations dying in storage. Active research on this problem is underway at Ft. Collins and Starkville. Until better information is available on the potential for genetic damage, conventional seed storage should remain as only a supportive technology for *ex-situ* conservation.

This supportive role could be very helpful for recalcitrant species also. Although long-term storage through conventional means is out of the question for both types of recalcitrant species, short-term success with a few genera (Quercus, Fagus) suggest that with special care (slow drying, cryoprotectants) storage life of many tropical recalcitrant seeds might be extended enough to facilitate establishment of ex-situ plantations. Long-term storage of all recalcitrant seeds is the greatest challenge in seed science today. Storage by conventional seed storage methods is not the answer, but it can be useful in some situations. Current research on storage of recalcitrant seeds can be found at the University of Reading, U.K. (tropical), Kew Gardens, U.K. (tropical); Institute of Dendrology, Kornik, Poland (temperate); Tropical Agriculture Research Center, Japan (tropical); and Pertanian University of Malaysia (tropical). Storage of temperate species was studied at the Forestry Sciences Laboratory in Starkville, Mississippi until 1982.

D. Cryogenic Storage

Cryogenic storage of seeds is a promising technology currently in the research stage. It deserves much increased research emphasis. For true orthodox and sub-orthodox seeds it may provide safe storage much beyond the normal long-term definition. Research needs are the same as those for conventional storage: (1) what is the potential safe storage period, and (2) what is the potential for genetic damage to the population during storage?

For both types of recalcitrant species there are two aspects (at least) which deserve considerable research effort. One is the use of cryoprotectants to extend the short storage lives of this group. Secondly, the use of excised embryos of recalcitrant seeds in cryogenic storage should be studied further. While long-term storage of naked excised embryos does not appear practical, encapsulation of the embryos with artificial coatings opens the door to other possibilities.

The primary research effort in this field in the United States is at the National Seed Storage LAB (ARS) Ft. Collins, although tree seeds have been a very minor part of their research. Other cryogenic storage work is at Pertanian University of Malaysia, where work with tropical recalcitrant seed will be done.

E. Storage of Pollen

At this time no additional actions are recommended in the field of pollen storage per se. It has a very low priority for germplasm conservation of trees. The use of pollen tissue in micropropagation is included in the following section.

F. Micropropagation Tissues

From the standpoint of germplasm conservation, this technology is still in the early research stage. Yet for recalcitrant species, especially the tropical recalcitrants, this approach is very promising. Advances in micropropagation are being made rapidly, and research with tropical recalcitrant species should be promoted immediately. Short-term conservation of tropical hardwoods by tissue or cell culture could save valuable gene groups from disappearing natural stands until other methods for seed storage or ex-situ conservation can be sufficiently developed for operational success. Considerable research investment will be required.

Micropropagation of commercially valuable species with orthodox seeds must be pursued also, as the same benefits for germplasm conservation exist for them. It will not be as difficult to promote research with the species as it will be for tropical recalcitrants, because the commercial interest will attract private sector funding. At least two large private industries are active in forestry micropropagation research and development: Weyerhaeuser

Corporation and Hilleshog A.B. of Sweden.

Because of its "biotechnology" connotation, micropropagation is a very popular research field in the United States and abroad. There are many good laboratories at U.S. universities, but some with demonstrated excellence with trees are: University of California at Berkeley, University of Wisconsin, Oregon State, Texas A & M, North Carolina State, and University of Georgia. The Forest Service does not have good in-house capability in micropropagation research.

IV. RECOMMENDED INSTITUTIONAL ACTIONS

(numbers refer to the priority of actions.)

A. *In-situ* Conservation

government -

(1) Establish a national policy committed to conserving forest germplasm to insure further genetic diversity.

(1) Increase international activities for *in-situ* conservation, primarily through support of existing institutions. Recommended annual contributions:

IUCN - $100,000 to complete documentation of protected areas. Immediate results; continue for 10 years.

FAO - $300,000 to assist developing countries map and inventory prospective conservation stands. Results within 3 years; continue for 10 years.

These contributions could be redirection of USAID funds.

(2) Instruct the USDA Forest Service to carry out inventories of forest resources to determine the extent of germplasm conservation required in the United States and to store the data in a central

data bank. This may require new funding of about $200,000 per year to complete the job in 5 years.

(2) Direct cooperation between all Federal land management agencies to insure a unified effort to identify and conserve the needed ecosystems on government lands in the United States, as identified by the USDA Forest Service.

others -

Supportive roles only. The long-range activities that these actions require are best carried out by governments.

The actions described above can bring about the conservation of many (but not all) important gene complexes through preservation of entire ecosystems. With proper protection (both political and biological) these gene complexes will be available for further selection, improvement and manipulation. No other action can save so much diverse genetic material. It is clearly in the self-interest of the United States to help conserve tree germplasm of the moist and dry tropical regions.

B. *Ex-situ* Conservation

government -

(1) Establish *ex-situ* conservation stands for populations which cannot be saved *in-situ* (e.g. hardwood forests being lost to reservoir flooding).

(1) Fund research on the study of reproductive biology and seed technology of tropical recalcitrant species. Research on vegetative propagation would be included. This can best be done through USAID funding for research networking or partnerships involving universities in developing countries and in the United States. A minimum of $5 million per year is

recommended for 10 years. Universities in this country with the necessary expertise include: Oregon State, Iowa State, Mississippi State, North Carolina State, and Michigan State.

(1) Increase support of international efforts to collect seed and establish ex-situ conservation stands in other countries. This support should be through FAO and its cooperating institutions (CFI, DANIDA, etc.). Annual funding of $500,000 should be made available to FAO for seed collection, ex-situ stand establishment, and consultants to help developing countries. Some results, such as seed collection, would be immediate. This funding should be maintained for 10 to 15 years. An additional $100,000 yearly should be allocated to the Forest Service tree seed exchange program to bring our program up to the level of other developed countries.

(2) Work for international agreements which will: (a) Ease plant and seed import/export restrictions to allow better international movement of material for ex-situ plantings. (b) Guarantee access to ex-situ material by cooperating scientists and tree breeders.

universities -

(1) Carry out basic research on the reproductive biology of recalcitrant species, both with and without government funding (see above).

(2) Carry out applied research on seed technology and plantation establishment.

private sector -

(1) Allow collection of reproductive material on all lands for the purpose of ex-situ conservation.

(2) Offer planting sites for ex-situ conservation and the required protection.

(3) Agree to preserve first-generation seed orchards past their commercial prime as areas of ex-situ conservation.

The research on reproductive biology and seed technology of tropical recalcitrant species will be beneficial for all reforestation in the tropics, whether intended for ex-situ conservation or not. Chin (1984) stated that, "The most common problem in afforestation programmes in developing countries of the tropics is the inadequate supply of viable seeds." Without a good seed supply, tropical deforestation cannot be reversed.

C. Conventional Seed Storage

government -

(1) Promote and fund research on long-term storage and the accompanying genetic damage of seeds of economically valuable true orthodox and sub-orthodox species. First-year funding of $100,000 should go to both the Ft. Collins and the Starkville laboratories to expand their current research on storage to include additional species. After the initial expense of seed acquisition, $30,000 per year should be budgeted to each laboratory to maintain these long-term studies. Preliminary results would be available in 10 years (on genetic damage), with final results 50 to 100 years away.

(1) Promote and fund research to extend storage life of economically valuable temperate and tropical recalcitrant species on a short-term basis. Funding for storage of temperate species should be a minimum of $50,000 per year to the Forest Service for 10 years. Some results will be possible in 5 years.

universities -

(1) Participate in the research activities listed above as appropriate.

Successful research in the two areas listed above would hopefully extend storage life of seeds as follows:

true orthodox - 100 years
sub-orthodox - 50 years
temperate recalcitrant - 5 to 10 years
tropical recalcitrant - 2 to 3 years

Knowledge of genetic damage also must be available to allow proper evaluation of the technology.

D. Cryogenic Storage

The proposed actions for all parties are the same as those proposed for conventional seed storage. The goals are the same also, but the expectations for success in cryogenic storage should be more:

true orthodox - 200 years
sub-orthodox - 100 years
both types of recalcitrant - 100 years.

If storage life potentials turn out to be little more than those of conventional storage, then there would be little advantage of cryogenic storage, unless it provides more genetic stability. An additional annual funding of $100,000 should go to the National Seed Storage Laboratory for a 10-year period to develop the basic technology of cryogenic storage for tree seeds. Procedures for orthodox tree seeds will be nearly the same as those for orthodox crop seeds, but considerable research must be done on both types of recalcitrant seeds.

E. Storage of Pollen - No action.

F. Micropropagation Tissues

government -

(1) Promote and fund research on micropropagation techniques, for all types of orthodox and recalcitrant species. Goals would be short-term preservation of valuable germplasm in danger of being lost and long-term storage of cultures by cryogenic means. Approximately $1.5 million per year for up to 10 years should be allocated for grants to capable universities through a competitive process administered by the Forest Service. The basic technology should be in hand within 10 years, and then lesser amounts would be needed to evaluate long-term storage. This phase of the work should be done in USDA facilities because of the long-term nature of the work.

universities -

(1) Participate in this research through the process outlined above.

private sector -

(1) Carry out research and development on micropropagation techniques of economically valuable species.

G. Strategies for Conservation by Species Groups

Groups listed are by priority, based on economic and environmental values and current research needs.

1. Moist tropical hardwoods (seeds mostly tropical recalcitrant)
    a. Increase in-situ conservation, based on improved forest inventories of remaining natural stands.
    b. Concentrate research on reproductive biology (sexual and asexual), conventional seed storage, and micropropagation techniques.
    c. Increase ex-situ plantings, with emphasis on multi-purpose species and material from natural forests undergoing clearing.

   d. Establish an international data bank of in-situ and ex-situ conservation areas. Ex-situ data would include origin, date of planting, etc.

2. Tropical and sub-tropical arid zone species (seeds mostly true orthodox)
   a. Increase both in-situ and ex-situ conservation.
   b. Increase plant exploration, seed collection, and provenance trials to broaden species and genetic bases. Put more emphasis on multi-purpose species.
   c. Support research on conventional seed storage, seedling production, and plantation establishment.
   d. Same as 1.d.
3. Tropical conifers (seeds true orthodox or sub-orthodox)
   a. Establish more in-situ conservation.
   b. Increase research on seed collection, handling, and conventional storage.
4. Temperate conifers and hardwoods (seeds true orthodox or sub-orthodox)
   a. Survey and document present in-situ and ex-situ conservations. Take steps to conserve provenances not presently covered.
   b. Double level of research on cryogenic storage.
   c. Increase research on long-term storage of micropropagation tissue.
   d. Maintain research on conventional seed storage, with emphasis on determining maximum storage life and associated genetic damage.
5. Temperate recalcitrant species

a. Same as 4.a.

b. Increase research on mircopropagation, and how to accomplish long-term storage of the tissues.

c. Maintain research on cryogenic storage.

V. SUGGESTED CONGRESSIONAL ACTIONS

A. Pass legislation to establish a national policy committed to conserving forest germplasm to insure future genetic diversity. The legislation should direct cooperation between all federal land management agencies to insure a unified effort to identify and conserve the needed ecosystems on government lands and to survey and document similar conservation on non-federal lands. The USDA Forest Service should coordinate this action. Failure to take this action will perpetuate the current unorganized condition, in which the public favors germplasm conservation, but no one has the responsibility of doing it.

B. Increase funding to appropriate agencies to allow greater United States involvement and contribution to international plant exploration and exchange of seed and other reproductive material. This action should lead to increased *ex-situ* conservation of valuable germplasm, including that of U.S. species. It should also upgrade our seed exchange program to at least equal that of other countries. Not only will these steps demonstrate to the world our concern over germplasm conservation, but they may increase opportunities for international trade for the private sector. One disadvantage of working through international organizations is that their priorities may not exactly match ours.

C. Encourage international agreements which facilitate exchange of tree reproductive material and guarantee later access to the material by foreign scientists. One view of this action might be that plant health regulations should not be relaxed because of threats of introduced pests. Proper controls can still be maintained, however, with better exchange of material. A very important aspect of this action would be improved data bases which would be accessible to all participating scientists.

D. Increase research funding for high-priority items. These are:

a. National Seed Storage Laboratory (ARS) to include tree seeds in cryogenic storage research and conventional seed storage research programs.

b. USDA Forest Service for conventional seed storage, genetic damage during storage, and storage of temperate and tropical recalcitrant seed programs.

c. Various universities or government laboratories through competitive grants to develop micropropagation techniques and evaluate their capacity for short- and long-term storage of tree germplasm.

Opposition to these actions can be based on economic terms, which would imply that budget deficits will not allow increases. An opposing view is that if these technologies are not developed now, the future costs to the nation will be much greater. If budgetary constraints become too great, then research funds should be re-directed from other programs. These technologies are crucial.

E. Increase funding in USAID for tree seed programs in developing countries. Research on-site in the tropics should be emphasized thru: (1) training foreign seed scientists in the United States, (2) visiting scientists program for United States seed scientists, (3) research partnerships between universities in the United States and universities in developing countries, and (4) encouraging joint tree seed/agricultural seed research laboratories in developing countries where appropriate. (Often facilities and trained staff are in short supply, so one laboratory deals in both commodities. USAID programs do not adjust well to this pattern; agriculture and forestry are separated.)

This sort of program is the best approach to tropical problems. Facilities may not be always sufficient in developing countries, but much of the research must be done on-site. A critical element will be the involvement of technically competent U.S. researchers in the partnerships. This action could possible be accomplished by redirection of current funding instead of new appropriations. In that case action by USAID, and not Congress, would be needed.

Literature Cited

Anonymous, "Seed Catalogue, January, 1985," DANIDA Forest Seed Centre, Appendix 5. Humlebaek, Denmark, 1985.

Anonymous, "Seed List of the Latin American Forest Tree Seed Bark," Centro Agronomico Tropical de Investigacion y Ensenanza, Turialba, Costa Rica, 1983, 10 pp.

Barnett, J. P. and Vozzo, J. A., "Viability and Vigor of Slash and Shortleaf Pine Seeds After 50 years of Storage," *Forest Science* 31: 316-320, 1985.

Bass, L. N., National Seed Storage Laboratory, USDA Agricultural Research Service, personal communication, 1985.

Bonner, F. T., "Storing Red Oak Acorns," Tree Planters Notes 24(3): 12-13, 1973.

Bonner, F. T., "Storage Principles For Tropical Tree Seed," *Proceedings Reunion Sobre Problemas en Semillas Forestales Tropicales*, San Felipe - Bacalar, Quintana Roo, Mexico: Instituto Nacional de Investigaciones Forestales, Pub. Especial No. 35, 1981.

Bonner, F. T., "New Forests From Better Seeds: The Role of Seed Physiology," *Seedling Physiology and Reforestation Success*, Duryea, M. L. and Brown, G. N. (eds)., Dordecht, the Netherlands: Martinnus Nijhoff/Dr. W. Junk Publishers, 1984, pp. 37-59.

Bonnet-Masimbert, M. and Muller, C., "La Conservation des Fâines est Possible," Revue Forêts France 27: 129-138, 1975.

Chin, H. J., "Human Factors Affecting Seed Quality - A Malaysian Experience," *Proceedings Seed Quality of Tropical and Sub-Tropical Species*, Bangkok, Thailand: IUFRO Project Group on Seed Problems, May 22-26, 1984 (in press).

Eliason, E. J. and Heit, C. E., "Red Pine Seed Shows High Germination After 42 Years in Storage," *Journal of Forestry* 71: 776, 1973.

FAO, *Forest Genetic Resources Information - No. 10*, Rome: Food and Agriculture Organization of the United Nations, 1981, 55 pp.

FAO, *Report of the Fifth Session of the FAO Panel of Experts on Forest Gene Resources*, Rome: Food and Agriculture Organization of the United Nations, 1984, 101 pp.

Grout, B. W. W.; Shelton, K.; and Pritchard, H. W., "Orthodox Behavior of Oil Palm Seed and Cryopreservation of the Excised Embryo For Genetic Conservation," *Annals of Botany* 52: 381-384, 1983.

Jonas, P. S., "A List of Seed in the Canadian Forestry Service Seed Bank," Information Report Pl-X-39 E/F, Petawawa National Forestry Institute, Canadian Forestry Service, 1984, 63 pp.

Karrfalt, R. National Tree Seed Laboratory, USDA Forest Service, personal communication, 1985.

King, M. W. and Roberts, E. H., *The Storage of Recalcitrant Seeds - Achievements and Possible Approaches*, Rome: International Board for Plant Genetic Resources, 1979, 96 pp.

King, M. W.; Soetisna, U.; and Roberts, E. H., "The Dry Storage of *Citrus* Seeds," Annals of Botany 48: 865-872, 1981.

McKeand, S. E. and Wier, R. J., "Tissue Culture and Forest Productivity," *Journal of Forestry* 82: 213-218, 1984.

Palmberg, C., "Genetic Resources of Arboreal Species: FAO Activities," *Proceedings Seed Quality of Tropical and Sub-Tropical Species*, Bangkok, Thailand: IUFRO Project Group on Seed Problems, May 22-26, 1984 (in press).

Roberts, E. H., "Predicting the Storage Life of Seeds," *Seed Science and Technology* 1: 499-514, 1973.

Roos, E. E., "Genetic Shifts in Mixed Bean Populations. II. Effects of Regeneration," *Crop Science* 24: 711-715, 1984.

Sedjo, R. A. and Clawson, M., "How Serious is Tropical Deforestation?," *Journal of Forestry* 81: 792-794, 1983.

Stanwood, P. C. and Bass, L. N., "Ultracold Preservation of Seed Germplasm," *Plant Cold Hardiness and Freezing Stress*, L., P., and Saka, A. (eds), New York: Academic Press, 1978, pp. 361-371.

Sugawara, U. and Sakai, A., "Survival of Suspension Cultured Sycamore Cells Cooled to the Temperature of Liquid Nitrogen," *Plant Physiology* 57: 722-724, 1974.

Suszka, B., "Cold Storage of Already After-Ripened Beech (*Fagus silvatica* L.) Seeds," *Arboretum Kornickie* 20: 299-315, 1975.

Suszka, B. and Tylkowski, T., "Storage of Acorns of the English Oak (*Quercus robur* L.) Over 1 - 5 Winters," *Arboretum Kornickie* 25: 199-229, 1980.

Suszka, B. and Tylkowski, T., "Storage of Acorns of the Northern Red Oak (*Quercus borealis* Michx. = *Q. rubra* L.) Over 1 - 5 Winters," *Arboretum Kornickie* 26: 253-306, 1982.

Tamari, C.; Tang, H. T.; and Domingo; "Prospect For the Storage of Dipterocarp Fruits," *Proceedings Seed Quality of Tropical and Sub-Tropical Species*, Bangkok, Thailand: IUFRO Project Group on Seed Problems, May 22-26, 1984 (in press).

Thompson, D. G., "Clonal Reforestation: Forests of the Future," *Seedling Physiology and Reforestation Success*, Duryea, M. L. and Brown, G. N. (eds), Dordrecht, The Netherlands: Martinnus Nijhoff/Dr. W. Junk Publishers, 1984, pp. 3-28.

Timothy, D. H. and Goodman, M. M., "Germplasm Preserv ation: The Basis of Future Feast or Famine: Genetic Resources of Maize--An Example," The Plant Seed: Development, Preservation, and Germination, Rubenstein, I. et al (eds.), New York: Academic Press, 1979, pp. 171-200.

Turnbull, J. W. and Doran, J. C., "Role of the CSIRO Tree Seed Centre in Collection, Distribution, and Improved Use of Genetic Resources of Australian Trees," Proceedings Seed Quality of Tropical and Sub-Tropical Species, Bangkok, Thailand: IUFRO Project Group on Seed Problems, May 22-26, 1984 (in press).

U.S. Department of Agriculture, Forest Service, 1981 Directory of Forest Tree Seed Orchards in the United States, Washington, D.C.: U.S. Forest Service, FS-278, 1982, 48 pp.

U.S. Department of Agriculture, Forest Service, Report of the Forest Service - Fiscal Year 1983, Washington, DC: U.S. Forest Service, 1984, 167 pp.

U.S. Department of the Interior, Fish and Wildlife Service, Endangered and Threatened Wildlife and Plants, Reprinted from Federal Register 48 FR 34182-34196, 1983.

Wang, B. S. P., "Tree Seed and Pollen Storage For Genetic Conservation: Possibilities and Limitations," The Methodology of Conservation of Forest Genetic Resources: Report on a Pilot Study, Rome: Food and Agriculture Orga-ization of the United Nations, 1975, pp. 93-103.

Willan, R. L., Provenance Seed Stands and Provenance Conservation Stands, DANIDA Forest Seed Centre Technical Note No. 14, 1984, 42 pp.

Yap, S. K., "Seed Biology of Some Indigenous Timber Tree Species in Malaysia," Proceedings Seed Quality of Tropical and Sub-Tropical Species, Bangkok Thailand: IUFRO Project Group on Seed Problems, May 22-26, 1984 (in press).

Zobel, B. and Talbert, J., Applied Forest Tree Improvement, New York: John Wiley and Sons, 1984, 505 pp

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Causes of Loss of Biological Diversity

Norman Myers
Consultant

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CAUSES OF LOSS OF BIOLOGICAL DIVERSITY

Dr. Norman Myers
Consultant in Environment and Development,
Oxford, U.K.

> "The worst thing that can happen during the 1980s is not energy depletion, economic collapse, limited nuclear war, or conquest by a totalitarian government. As terrible as these catastrophes would be for us, they can be repaired within a few generations. The one process ongoing in the 1980s that will take millions of years to correct is the loss of genetic and species diversity by the destruction of natural habitats. This is the folly that our descendants are least likely to forgive us."
>
> Professor Edward O. Wilson, Harvard University.

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CAUSES OF LOSS OF BIOLOGICAL DIVERSITY

Dr. Norman Myers

I. INTRODUCTION

The loss of biological diversity--defined in this paper to mean the full array of differentiated life forms, both animals and plants, that make up the Earth's stock of species and their significantly distinct units such as subspecies, races and populations--is one of the major environmental phenomena of our times. The problem no longer lies, as was the case until a few decades ago, with deliberate and wanton over-exploitatioin of wild creatures through e.g. hunting and trapping. Rather the problem now lies, as concerns at least 99.9 percent of extinctions, with loss of wildlife habitat and disruption of life-support sytems, i.e. indirect and unwitting destruction of wildlife.

As we shall see, the planetary spectrum of biological diversity is undergoing depletion at ever-faster rates. If present land-use trends persist--and, in the absence of greatly increased conservation measures, they are likely to accelerate--we can reasonably suppose that loss of wildlife habitat will, by the middle of the next century or shortly thereafter, lead to the elimination of at least one quarter, possibly one third, and conceivably even more of all Earth's species (Ehrlich and Ehrlich, 1982; Myers, 1979, 1984, 1985 and 1986; Raven, 1980; Soule, 1986). This will represent a greater biological debacle, in terms of numbers of species involved and the compressed time-scale of the episode, than any mass-extinction since the demise of the dinosaurs and associated species 65 million years ago. Worse, the process may well eliminate not only large numbers of species but many broadscale ecosystems, indeed entire biotic provinces. This means that there will surely be a marked impoverishing impact on the future course of evolution, insofar as the process will eliminate some of the "resource stocks" on which natural selection and other processes of evolution work their creative effects to generate a new species. As has been well expressed (Soule and Wilcox, 1980), "Death is one thing; an end to birth is another." In this sense, the impending extinction spasm may well rank, in terms of its overall impact on the longer-term future, as one of the greatest setbacks to life's diversity on Earth since the first appearance of life almost 4 billion years ago.

II. NUMBERS AND DISTRIBUTION OF SPECIES

Before we inquire into the rates of extinction, we need to ask how many species exist on Earth. Our response to this question will tell us something about how much, or how little, we know about the species issue in terms of our basic scientific understanding--and what, in turn, this says about our informed grasp of the extinction phenomenon that is overtaking Earth's biotas.

To date, scientists have identified 1.6 million species worldwide, of which around one million exist in the temperate zones, 100,000 or so in the boreal zones, and the rest in the tropics. Many more remain unidentified. By extrapolating from species inventories in discrete locations, we can reckon there are at least 4.6 million, and more likely 5 million, species in all. Many scientists believe that the true total is probably nearer 10 million: they reason this on the grounds that the tropics are much richer in species than the rest of the planet, while remaining by far the least investigated. Indeed some recent research (Erwin, 1983) suggests, on the basis of limited findings, that the tropical forest biome alone could harbour 30 million insect species alone.

So far as we can roughly judge, some two-thirds of all species occur in the tropics. This is significant because the tropics are roughly coextensive with the developing nations, which largely lack the conservation resources (scientific skills, funds, institutional capacity) to do a worthwhile job. More important still, it now appears that around half of all species occur in tropical forests, which nevertheless cover only 7 percent of Earth's land surface. On-the-ground research reveals, for instance, that the forests support at least 90,000 species of higher plants (by contrast with only 50,000 in the entire northern temperate zone, with its vast territories in North America and Eurasia). Roughly speaking, and assuming the global total is only 5 million species, tropical forests in Latin

America support one million species of both plants and animals, those of Southern and Southeast Asia three-quarters of a million (the bulk of them in Southeast Asia), and those of Africa one third of a million. Despite their extreme biological richness, tropical forests are being depleted faster than any other ecological zone (see below).

Furthermore, we should bear in mind that biological diversity occurs within species as well as among species. So it is not enough to focus entirely on the species level, even though, for reasons of space, this paper will confine its attention mostly to species rather than sub-units of species. Virtually all species harbour a far greater amount of biological diversity, in the form of genetic variability, than is suggested by the concept of species alone. Each species generally comprises a number of subspecies, races and populations, each of which constitutes a distinctive reservoir of genetic materials. Although intraspecies genetic differences are sometimes slight, they can often be markedly different. An idea of this "genetic plasticity" inherent in a species can be gained, for example, by considering the variability manifested in the many races of dogs, or the many specialized types of corn developed by plant breeders.

The biological diversity within species is all the more significant in that we know that many species are losing sub-units, such as races and populations, at a rate that greatly reduces their genetic variability. Even though these species are not being endangered in terms of their overall numbers, they are undoubtedly suffering a decline in their genetic stocks. For example, the remaining gene pools of major crop plants such as corn and rice amount to only a fraction of the genetic diversity they harboured only a few decades ago, even though the species themselves are far from threatened.

We have looked at this background in some passing detail, since it is important to know (a) how much, and how little, we know about species totals overall, and of their genetic constituents; and (b) where the greatest concentrations of biological diversity occur.

III. CAUSES OF EXTINCTIONS

As we have seen, virtually all threats to biological diversity are due to loss of habitats and life-support systems. These may be classified as indirect sources of depletion. It is not species themselves that are under pressure, but their living space. Yet while this has always been the cause of most depletion (that is, when we consider undocumented as well as documented depletion), there are numerous instances of direct reduction of species' numbers, and of outright extinctions. We shall consider these direct reductions first.

Direct Depletion

The most usual form of direct depletion is hunting, or rather over-hunting, for meat, furs, and other products. Among obvious examples are the great whales, plus other marine mammals such as seals and dolphins; a lengthy list of marine fisheries, such as the California sardine, the North Atlantic herring and the Peruvian anchovy; various large cats, such as the tiger, the clouded leopard and the cheetah; and diverse birds, such as the great auk, the passenger pigeon and of course the dodo. All of these have been reduced to threatened status, or have been eliminated altogether, through the hand of man the hunter.

As examples of recent over-hunting and over-cropping, we can consider the case of the three main species of kangaroo (red, eastern grey and western grey) in Australia. Some 19 million animals were harvested in 1981; and in 1983, exports of meats and skins were worth $12.4 million (Inskipp, 1985). A good many local populations of kangaroo have been markedly depleted. The trade in tropical birds has now topped 10 million specimens a year, and can be estimated as some $70 million in value--causing numerous populations, and in some cases species, to be reduced in numbers (Inskipp, 1985). Similarly the trade in tropical fish is now estimated to be worth $750 million a year, again with excessive, i.e. non-sustainable, offtake in the case of many species (Barzdo, 1985). Even butterfly wings are becoming important as trade items (Vietmeyer, 1985). They serve as ornamentations for coffee tables, display cases, trays, screens, even toilet seats. Exports from Taiwan alone are estimated at anywhere between 40 million and 500 million pairs of wings a year, and the value of total international trade is now reputed to have topped $20 million a year. This lucrative business is exerting unsustainable pressures on certain butterfly species, such as several of the swallowtail species.

Among the most prominent groups of creatures in international trade is the primates. Of around 180 species in all, no fewer than 108 are harvested for international trade, the main ultimate end-purpose being medical research. In 1982, the volume of trade amounted to 30,000 animals (down from an estimated 200,000 in 1952), worth around $4.25 million (Conservation Monitoring Centre, 1985). Of this 1982 trade, the United States accounted for more than half, Great Britain for about one-fifth. Japan for one-seventh, and Canada for one-tenth, among some 60 other importing countries. Major exporters included Indonesia, more than one third of the total; Philippines, almost one-sixth; Malaysia, over one-seventh; and Bolivia, about one-tenth, among some 50 other exporter nations. The species most heavily harvested include the long-tailed macaque, principally exported by Indonesia, Philippines and Malaysia. The pig-tailed macaque is traded much less, but may be more seriously threatened in the wild through trapping. Among other species experiencing depletion through international trade are the squirrel monkey from Bolivia and Guyana, and the green monkey from Kenya, Ethiopia and Somalia. Fortunately the chimpanzee, while formerly traded in large numbers, has now been largely relieved of hunting pressure. But the golden-lion tasmarin of coastal Brazil, with only 1000 at most in the wild, lost 29 through a single shipment to Brazil in 1983 (Mack and Mittermeier, 1984).

Probably the most salient instances of over-hunting in the recent past concern the elephant and the rhinoceros in Africa.

The price of elephant ivory has increased from $3 per kg. in 1970 to more than $50 in 1985; and the volume exported from Africa now runs to around 100,000 tons a year, or the equivalent to tusks from some 90,000 elephants--out of a total elephant community in Africa of fewer than one million animals (Western, 1985). As for rhinos in Africa, both black and white species, in 1980 there were still around 15,000 black rhinos but by early 1985 there were fewer than half as many (in the Central African Republic, numbers have declined from 3000 to about 150). As for the white rhino, the southern race has actually increased its numbers a little in recent years, from 3020 to 3920; but the northern race has declined from almost 1000 to one dozen at most (Hillman, 1985).

So much for animals. In the case of plants, it is man the collector who does the damage. Prime trophies are orchids of various kinds. In 1982 the U.S. legally imported 17,759 orchids from Mexico, or which only 2800 were artificially propagated (Fuller, 1985). Still more sought after are cacti. In 1977 the United States' legal imports of succulents, mostly cacti, from Mexico, totalled 7 million individual plants; illegal imports were also sizeable (Campbell, 1984). In Mexico there grows, or rather there grew, a cycad, that is not known to be artificially propagated to any worthwhile extent. In 1982 United States importers received 1200 cycads from Mexico, which are believed to have comprised the entire wild population of the species, leaving it extinct in Mexico (Wildlife Trade Monitoring Unit, 1984).

Since the nature and extent of direct depletion of biological diversity are generally well known, and since direct depletion is much less important than indirect depletion, we shall not deal further with the issue here.

Indirect Depletion

Indirect depletion is far more significant than direct depletion, on the grounds that it is unselective and more sweeping in its scope. If a hunter goes into a tract of tropical forest and shoots out its tiger population, that is one thing. But it is another thing if he chops down the forest, and thus eliminates the survival capacity of entire communities of species, both animals and plants.

Let us open this section by taking a lengthy look at the biome that is as biologically rich as all other biomes put together, viz. tropical forests. It features a good three-quarters, and possibly a still larger proportion, of all current extinctions--a situation that seems likely to persist into the foreseeable future of the next several decades. Hence it is worth our while to examine the tropical forest situation in some detail.

1. Tropical Forests

There is general agreement that remaining primary forests now cover rather less than nine million square kilometres; that between 76,000 and 92,000 square kilometres were being eliminated outright each year during the second half of the 1970s; and that a further 100,000 sq.kms. were being grossly disrupted each year (the rates can be assumed to have increased somewhat by today)

(FAO and UNEP, 1982; Hadley and Lanly, 1982; Houghton et al., 1985; Melillo et al., 1985; Molofsky et al., 1986; Myers, 1980, 1984 and 1985). This means, roughly speaking, that one percent of the biome is being deforested each year, and slightly more than another one percent is being significantly impoverished.

Since the amount of forest affected each year is expanding progressively, due principally to increase in numbers of slash-and-burn cultivators (see below), a simple projection of existing and well-established trends indicates that by the end of the century there could well be little left of the biome in primary status, with full complement of species, outside of two large remnant blocs, one in the Zaire Basin and the other in the western half of Brazilian Amazonia, plus some outlier areas such as the Guyana tract of forest in northern South America and perhaps parts of New Guinea. Moreover, these relict sectors of the biome are little likely to survive beyond a few further decades, again because of sheer buildup of human numbers if for no other reason.

To help us gain a concise insight into the present situation, let us look briefly at three particular areas, viz. the forested tracts of western Ecuador, Atlantic-coast Brazil and Madagascar. Each of these areas features, or rather featured, exceptional concentrations of species, with high levels of endemism, which has made them much richer (in biological senses) than other areas--and has left them more susceptible to acute biotic impoverishment as their environments become grossly disrupted through human hand. Western Ecuador is reputed to have once contained between 8000 and 10,000 plant species, with an endemism rate somewhere above 60 percent (Gentry, 1982). If we suppose, as we reasonably can by drawing on detailed inventories in sample plots, that there are between 10 and 30 animal species for every one plant species, the species complement in western Ecuador must have amounted to about 200,000 in all. Since 1960, almost the entire forest cover of western Ecuador has been destroyed, to make way for banana plantations, oil exploiters and human settlements of various sorts. How many species have thus been eliminated is difficult to judge, but they must be tens of thousands at a minimum. (Of course if the area had been designated a conservation priority ahead of time, large numbers of species could surely have been saved, at relatively limited cost.)

Rather similar baseline figures, and a similar story of forest depletion, though for different reasons and over a longer time period, apply to the Atlantic coastal forest of Brazil (Mori *et al*., 1981), and to Madagascar (Rauh, 1979).

So in these three areas alone, with their 600,000 species, at least two-thirds of them endemics, the recent past must have witnessed a sizeable fallout of species (Myers, 1986; Raven, 1985). In fact it is not out of order to suggest that in just these areas, the extinction rate could well have averaged several species a day since 1950 or so.

As for the future of tropical forests, the situation seems all the more adverse, in that it appears likely to feature an extinction spasm, and biological impoverishment generally, on a scale far greater than we are witnessing now (Myers, 1985 and 1986). We can identify a good number of other sectors of the biome that are ultra-rich in species, that feature high levels of endemism, and that likewise face severe threat of destruction. They include the Mosquitia Forest of Central America; the Choco Forest of Colombia; the Napo center of diversity in Peruvian Amazonia, plus six other centers (out of 20-odd centers of diversity in Amazonia) that lie around the fringes of the basin and hence are unusually threatened; the Tai Forest of Ivory Coast; the montane forests of East Africa; the relict wet forest of Sri Lanka; the monsoon forests of the Himalayan foothills; northwestern Borneo; the Maladive Islands of Indonesia; certain lowland areas of the Philippines; and several islands of the South Pacific (New Caledonia, for instance, with 18,340 sq. kms., or about the size of New Hampshire, contains 3000 plant species, 80 percent of them endemic).

These 20 sectors of the tropical forest biome amount to roughly one million square kilometres, or less than one-tenth of remaining undisturbed forests. So far as we can best judge from their documented numbers of plant species, and by making substantiated assumptions about the numbers of associated animal species, we can reckon that these 20 areas surely harbour one million species. If present land-use patterns and exploitation trends persist, there will be little left of their forest cover, except in the form of degraded remnants, by the end of this century or shortly thereafter. Thus deforestation in these areas alone could well eliminate very large numbers of species, surely hundreds of thousands of species, within the next 20 years or so (Myers, 1985 and 1986).

What are the implications for biological diversity? We can offer no more than some best-judgement assessments--by distinct contrast with the traditional approach to the issue, which has focused, until recently, on species that are known to be threatened or to have become extinct. We can do little more, and no less, than point to the predominant aspect of the issue, and accept that broadscale deforestation must unavoidably lead to broadscale elimination of species. We have already looked at 20 key areas that feature exceptional biological richness and that face exceptional threat of degradation and destruction. In these areas alone, perhaps as many as one million species must be considered at risk.

Looking at the situation another way, we can reckon, on the basis of what we know about plant numbers and distribution, together with what we can surmise about their associated animal communities, that almost 20 percent of all species on Earth occur in forests of Latin America outside of Amazonia; and another 20 percent in forests of Asia and Africa outside the Zaire Basin. All of the forests in which these species occur may well disappear by the end of this century, or early in the next at the latest. If only half of the species in these forests disappear, this will amount to at least three-quarters of a million species (Raven, 1985).

But what evidence is there to support the view that tropical forests will continue to disappear for a good while to come? As we have noted, the major problem for tropical forests is the slash-and-burn cultivator, who accounts for much more injury to forest habitats and life-support systems than all other agents (the commercial logger, the cattle rancher and the fuelwood gatherer) together (Myers, 1984). There are now some 250 million of these smallscale farmers. The problem does not lie with the shifting cultivator of traditional agricultural lifestyle, who, as long as his numbers were not unduly large, practiced sustainable use of forestland ecosystems. The problem now lies with the shifted cultivator, being the man who finds himself landless in established farmlands of countries concerned, and heads for the last unoccupied and "free" land available, the forests. In many areas his numbers are increasing at rates between four and eight percent per year, due in part to natural increase and in part to immigration. In light of population projections for the countries in question, and the already excessive pressures on established farmlands, we must anticipate a rapid increase in slash-and-burn pressures from these farmers. Details are set out in Table 1. It is hard to see how the deteriorating situation that is now overtaking tropical forests will not continue to deteriorate ever-more rapidly.

As a measure of what rapid population growth can impose on tropical forests, let us note the situation in Rondonia, a state in the southern sector of Brazilian Amazonia. Since 1975, the population has grown from 111,000 to more than one million today, i.e. an almost 10-times increase in little over 10 years. In 1975, 1200 sq. kms. of forest were cleared. By 1982, this amount had grown to more than 10,000 sq. kms. and to 16,000 by early 1985 (Fearnside, 1985; Tucker *et al*., 1984; Wilson, 1985).

In sum, the prognosis for tropical forests and their species is distinctly unfavourable, whether in immediate or long-term senses. Within another half century or so, we may lose one quarter, conceivably a still larger share, of all Earth's species in these forests alone. Since this outlook is so dire, let us check the findings by one further form of analysis, via some calculations on the part of a noted biogeographer, Simberloff (1985).

Reviewing the case of Amazonia, Simberloff concludes that if deforestation continues at present rates (they are likely to accelerate) until the year 2000, but then were to halt completely, we should anticipate a loss of about 15 percent of all plant species. This calculation is entirely reasonable and documentable, based as it is on the well-established theory of island biogeography and abundant evidence of pervasive deforestation patterns in Amazonia (Myers, 1984; and see section of Rondonia above). Were Amazonia's forest cover to be ultimately reduced to those areas now set aside as parks and reserves, we should anticipate that 66 percent of plant species would eventually disappear, together with almost 69 percent of bird species, and similar proportions of all other major categories of species. Of course we may learn how to manipulate habitats to enhance survival prospects. We may learn how to propagate threatened species in captivity. We may be able to apply other emergent conservation techniques, all of which could help to relieve the adverse repercussions of broadscale deforestation. But in the main, the damage will have been done. For reasons of island biogeography, and of "ecological equilibriation" (delayed fall-out effects), Simberloff believes that some extinctions in Amazonia would not occur until well into the 22nd century, or even further into the future. So a major extinction spasm in Amazonia is entirely possible, indeed plausible if not probable.

2. Other Tropical Biomes

As concerns other tropical biomes, we can note that coral reefs, wetlands and certain dryland savannahs are likewise being depleted at accelerating rates through human interference. As an example of a dryland savannah, the Cape Floristic Kingdom of South Africa measures only 18,000 sq.kms., yet it harbours 6000 plant species, 70 percent of them endemic. By comparison, the entire northeastern quarter of the United States, or 1.5 million sq. kms., possesses only about 5500 plant species, of which only a few hundred are endemic to the region. Due to human activities, especially agricultural expansion in the form of irrigated crop growing and livestock ranching, about 2000 species of the Cape's flora are threatened or endangered, as many as in the entire United States. Unless much stronger conservation measures are put in hand forthwith, a sizeable share of these 2000 species, perhaps as many as half, together with a proportionate number of animal species, could well be eliminated by the year 2000 (Hall et al., 1984).

Moreover, biological depletion can occur not only through destruction of wildlife habitats. It can arise through disruption of life-support systems, as in the instance of Lake Victoria. Until 1960 a number of indigenous fish species contributed to commercially-important fisheries. But after the 1960 introduction of the Nile perch, a piscivorous species, many indigenous species, not only herbivorous but carnivorous species, were entirely eliminated. Whereas the Lake's fisheries were formerly based on a wide range of species groups, they are now dominated by only four such groups (Barel et al, 1984). This adverse experience notwithstanding, there is now talk of introducing exotic species into Lake Malawi, which possesses one of the world's most species-rich fish faunas, and serves as a major laboratory of evolution.

We could tell a similar tale with respect to other biologically rich zones of the tropics that are unusually threatened through habitat destruction, e.g. coral reefs, mangrove ecosystems, and montane communities. There is not space here to describe all these separate instances. In each case, however, we can note that the situation is characterized by (a) exceptional concentrations of species, (b) exceptional levels of endemism, and (c) exceptional degrees of threat. So all in all, we can assert that the most pervasive disruption and destruction of wildlife habitats is occurring in tropical zones of the developing world--the very region that harbours at least two-thirds of all Earth's species.

3. Non-Tropical Zones

As for the rest of the world, the problem is not remotely so great, with the exception of island communities. Many species on islands are often endemic, which makes them specially liable to threat. Only 20 percent of all bird species are island birds, but 90 percent of birds driven extinct in historic times have been island dwellers. The vulnerability of island species is due largely to their tendency to evolve with specializations that suit them for survival in a confined locality where there are few competitors and usually predators. This evolutionary equipment leaves them grossly unable to cope with incursions by creatures brought in from outside by man, notably goats, pigs, rats, dogs and cats. What were formerly enclaves of security turn into "killing grounds" from which there is no escape. Island species are also ill-adapted to forest felling, grass burning, erosion, competition from alien weeds, and other disruptions on the part of man. Perhaps worst of all, many island creatures have lost the capacity to escape from dangers. Within the restrictive security of Mauritius, the dodo did not need to fly; when the white man arrived with guns and clubs, he found the bird all too easy to despatch. In the entire mascareno group of islands (some tropical as well as non-tropical), not just Mauritius but several others, an original stock of more than 70 endemic vertebrate species has now been reduced to only 24, 15 of which are endangered. All the rest have been accounted for by the concerted impact of rats and pigs, axe and plough. Fifty years after St. Helena was discovered by the white man in 1502, the island featured huge herds of goats, whereupon its plant life declined steadily. When a botanical inventory was made in 1810, 33 endemic plant species were recorded, of which 22 have since gone extinct, on top of the scores that disappeared before 1810 (IUCN, 1979).

Habitat disruption in temperate-zone lands of the developed world, where broadscale technology has exerted a longer-standing impact than in tropical zones, covers a broad spectrum of man's activities: agriculture and forestry, settlement schemes, highway construction, and pollution, among many other activities. In the continental United States, for instance, with its 15,000 plant species, around 1000 are considered threatened. In part this is because of expansion of urban communities and other built-up areas; one acutely endangered butterfly is confined to two patches of land near Los Angeles airport). In part too it is because of oil and mineral exploration and extraction, which in Alaska have depleted the tundra vegetation (in turn leading to decline in numbers of caribou and musk ox).

Similarly in Australia, overly competitive grazing from sheep and other domestic stock has threatened certain marsupials (IUCN, 1982). Grazing competiton affect many wild herbivores--and as wild herbivores fade from the scene, wild predators turn for prey to man's domestic herds, which in turn brings retribution on their heads. Of continental mammals eliminated in various parts of the world, around 40 percent have been large herbivores that have been overwhelmed by competition with man's domestic stock. In the Mongolian People's Republic, where 150,000 sq. kms. supported 640,000 people and 9.6 million head of livestock in 1920, and now contains more than twice as many people and two and a half times as many domestic stock, only remnant numbers remain of the wild bactrian camel and the Mongolian wild ass, while the tiger and other large predators have been wiped out (IUCN. 1979).

Another widespread form of habitat disruption in temperate-zone lands lies with pollution, notably agro-chemicals. In the United States, the peregrine falcon and the brown pelican have suffered from washoff of DDT from farmlands into watersystems such as rivers and lakes, also coastal ecosystems. A more recent form of pollution lies with acid raid; in Scandinavia, several species of fish have declined in numbers through acidification of their lake habitats; while in eastern Canada, a species of trout has been reduced to severely theatened status through the same cause (Organization for Economic Cooperation and Development, 1985).

One particular category of ecotopes in temperate-zone lands are being widely degraded if not destroyed, viz. wetlands. Wetland-living species clearly depend on water for much if not all of their life-cycles. Yet wetlands are unduly prone to modification, if not outright elimination, by man, who tends to see marshes, tidal flats and similar locales as "unproductive wastelands." In the United States, there were 510,000 sq. kms. of wetlands in 1850 (or roughly 5 percent of land surface), today only about 300,000 sq. kms.--and these residual areas are declining at a rate of about 2400 sq. kms. per year (Frayer *et al.*, 1983; Tiner, 1984; Ono *et al.*, 1983). As many as 50 percent of U.S. freshwater molluscs are endangered, or have become extinct; of 2000 inland snails some 400 are threatened (Davies, 1977). One snail used to range from Iowa to southern Ontario, but now survives only under the spray of the Chittenango Falls in Madison County, New York. In Western Europe, one third of amphibians are endangered, and a further large proportion are threatened; in Great Britain, general degradation of wetlands has reduced virtually all aphibians, including the common frog in many areas, to threatened status (Council of Europe, 1979).

So much, then, for a review of both direct and indirect causes of depletion of biological diversity. Plainly the indirect causes are predominant, by a very long way indeed. Until recently, it has been direct causes that have gained most attention, by virtue of the spectacular declines imposed on e.g. the great whales through over-hunting and other direct impacts. It is likely, however, that indirect factors have always played a greater part in extinctions, i.e. through loss of habitat and of life-support systems. Today it would be hard to argue that these factors account for less than 99 percent of all extinctions, more likely 99.9 percent.

Impact of Technological Innovations

Broadscale deforestation is obviously fostered by modern technology. The chainsaw can fell the largest tropical forest tree in a matter of minutes, whereas the same task with an axe might take a couple of days. The same of course applies to equipment for hauling away logs, and other aspects of forest exploitation.

The role of "big technology" need not be laboured. Rather let us look at a salient example, that of the Jonglei project in southern Sudan, aiming to drain part of the Massachusetts-sized Sudd Swamp (Myers, 1979). The White Nile flows in a huge semicircle through the swamp, and the project's aim is to bypass the swamp with a 350 km. canal (twice as long as the Suez Canal). The new canal will drain off 20 million cubic meters of water per day, or one quarter of average annual flow, possibly extending to another 23 million cubic meters later. The project will reduce evaporation losses by 4.7 billion cubic metres per year, or one-sixth of the White Nile's flow--a considerable saving.

As a result of this diversion of water, some 16,000 sq. kms. could be theoretically converted into a major grain-producing area. As is usual with tropical agriculture, this potential "bread basket" would attract many new insect pests. The best way to tackle these pests would be to utilize closely associated predators and parasites from the insect communities of the present swamps--and it is highly likely that the Sudd, being a long-established island of moisture amid a semi-arid zone, features an exceptionally rich array of species, many of them endemic. If it turns out that the Sudd's ecosystem is to be fundamentally modified by the Jonglei Canal, whole assemblies of species could go extinct in just a few years.

True, technology can assist the save-species cause in certain respects, notably through ex-situ conservation of plant seeds in gene banks. Seeds of many plant species, especially those of dry, small seeds, can often be stored dormant for long periods at a humidity level of five percent and a temperature of minus 20 degrees C. without undergoing physical damage or loss of genetic integrity. Within a small space, a single center can protect many thousands of species. For example, the National Seed Storage Laboratory at Fort Collins, Colorado, contains 100,000 samples of more than 1300 plant species, with a capacity for at least 500,000 samples.

But gene banks represent no absolute answer to the conservation of plant genetic resources (Justice and Bass, 1978). First, the technique simply does not work with many seed plants. This applies especially to most vegetatively propagated plants, for example, potato, cassava, members of the orchid family, and tree species such as apples and pears that do not breed true from seeds. In addition, the reservation applies to many tropical plant species, such as the cacao tree, whose seeds can be conserved outside the wild only with great difficulty. For the huge majority of species, botanists simply do not have enough information to say whether seed-bank storage could work or not.

Furthermore, many additional technical difficulties arise including low storage tolerance of many seeds, plus mutability of strains. Barley, for example, undergoes chromosomal damage during seed storage and beans are prone to genetic shifts. There can also be accidents in storage facilities. An entire year's stock of seed potatoes, held at the storage facility at Sturgeon Bay in Wisconsin, was destroyed through a power failure caused by blown fuses. On top of all this, there can be unwitting or deliberate disposal of strains--a far from uncommon occurrence.

All in all, then, off-site conservation serves as no more than a solid back-up measure for what must remain the number one strategy, viz. on-site conservation.

Two Aggravating Factors in the Third World: Population and Poverty

In addition to mega-technology as a source of biological depletion, and as we have seen with respect to forestland farmers in the tropics, the role of population growth can be significant, to say the least. Sheer increase in human numbers in the Third World leads, in conjunction with pervasive proverty, to conversion of wildland habitats to environments that are inimical to wild species (Myers, 1979 and 1984). So let us now move on to consider some factors of biological depletion that operate "at one remove", i.e. their impact on species is even more indirect, not to say diffuse, than that of mega-technology.

We should not suppose, of course, that population growth in itself is intrinsically threatening to biological diversity. In populous countries such as Japan and the Netherlands, for example, urbanization has prevented widespread disruption of wildlife habitat (Harrison and Rowley, 1984). But developing countries will not achieve a parallel degree of urbanization even by the end of the next century. There will be huge numbers of people still living in rural areas and pursuing agricultural lifestyles.

In fact, by the end of the next century there will be three-fifths more people living in rural areas in the Third World than there are today (World Bank, 1985). If they are forced to continue employing low-grade extensive agriculture, the tendency will be to spread to the farthest corners of what are now natural environments. If, on the other hand, they are able to practice efficient intensive agriculture they could make sustainably productive use of relatively limited sectors of their countries, with reduced impacts on wildlands. (OTA: no reference inserted here, since these findings are based on the writer's 15 years of field research in rural areas of the Third World, including 50-odd countries.)

But they will need technical inputs they can afford,and this, in turn, requires the full support of their governments. In short, the challenge is not only technological but political. As much attention should be paid to these broader perspectives of land use in the Third World, as to narrowly focused campaigns to safeguard threatened species. To reiterate a familiar theme: conservation and development must operate hand in hand.

To see how things are likely to work out in practice, let us consider the prospect for Kenya, a country that has established an outstanding conservation record by setting aside six percent of its territory as parks and reserves in order to protect its wildlife and threatened species. (OTA: no reference given here, since these findings derive generally from the author's 24 years of residence in Kenya, and his work with the African Directorate of Demographers.) Kenya's present population of almost 20 million people is pressing so hard on protected areas that the three leading conservation units are already losing portions of territory to land hunger. Yet Kenya is projected to reach a total of 165 million people before its population growth stabilizes in the year 2115.

The prospects, then, for Kenya's parks are bleak. Similar population pressures threaten protected areas in Uganda, Ethiopia, Zimbabwe, and several other countries in which the impoverished but expanding peasantry is forced to derive a living from a dwindling resource base. Protected areas in these countries may be eliminated by the early part of the next century. Other countries such as Tanzania, Zambia, Mozambique, Sudan, Cameroon and at least one dozen other countries in Africa with valuable genetic resources will suffer severe pressures on their protected areas within the first quarter of the next century. The situation is particularly acute in sub-Saharan Africa because of population growth rates, which are the highest in the world and are still increasing; and because of the increasing incidence of hunger, which forces rural agricultural communities to spread into hitherto undisturbed wildlands (Harrison and Rowley, 1984).

The detrimental impact of population buildup is reinforced by poverty. No person causes greater injury to natural environments than a hungry farmer. There are already 600 million of these "poorest of the poor", projected to reach at least one billion by the start of the next century and perhaps increasing to two billion by the time the developing world's population comes close tolevelling out at around 10 billion in the year 2100.

The subsistence peasant is often conscious of the fact that by over-using soils, grasslands and forests he is jeopardizing the resource base which could provide him a livelihood for an indefinite period of time; yet the urgent food requirements of the short-term preclude any conservation measures.

Impact of First-World Consumerism

Besides the subsistence farmer, the agent who is next most capable of environmental destruction is the person at the other end of the "economic scale": the super-affluent person who seeks more goods at "fair" prices. Communities in North America, concerned about increases in the cost of beef, foster, albeit unwittingly, the deforestation of Central America in order to supply ostensibly cheap beef for fast foods such as hamburgers (Myers, 1981). Beef seekers in Western Europe are starting to promote similar "deforestation linkages" in Amazonia. They also stimulate deforestation in Thailand through marketplace demand for inexpensive food supplements in the form of cassava for feed-lot cattle (Myers, 1984); and they foster a spread of commercial ranching into savannah zones of Kenya, Botswana and other countries of Africa with an eye to the beef-export trade (Myers, 1976).

These economic-ecologic linkages between the developed and the developing worlds seem likely to become more numerous, and more extensive in their impact, as the global economy becomes increasingly integrated. Thus the problem of species extinction reflects not only growth in human numbers, but growth in human consumerism--an aspect of the situation that is often accorded less than due attention by conservationists preoccupied with the basic issue of population explosion.

Moreover, it is apparent from the discussion above that the causes of indirect loss of biological diversity can become more complex as we delve more deeply into the issues involved. There are proximate, or immediate, factors, such as mega-technology; there are intermediate-impact factors, such as population growth; and there are far-removed, or ultimate, factors, such as First-World consumerism. It is important to recognize these socioeconomic and politico-cultural dimensions of the situation. An adequate response to the problem of biological depletion is not likely to rest with scientific and technical measures, nor with conventional conservation responses such as protected-area networks. These steps amount to no more than establishing islands in the face of the incoming tide. As the tide comes in higher and faster, the islands are likely to be swept away. The main response should lie with mitigating the power of the tide.

References

Aron, W.I.; and Smith, S.H.; "Ship Canals and Aquatic Ecosystems," *Science* 174: 13-20, 1971.

Barel, C.D.N., and 12 others. *Destruction of Fisheries in Africa's Lakes*. Nature 315: 19-20, 1984.

Campbell, F.T., "Trade in Cacti and Succulents Regulated by CITES," *Cactus and Succulent Journal* 56(5): 218-221, 1984.

Council of Europe. *Decline of Wetlands in Europe*. Council of Europe, Strasbourg, France, 1979.

Davis, G.M., "Rare and Endangered Species: A Dilemma," *Frontiers* (publication of the Academy of Natural Sciences of Philadelphia) 41(4): 12-14, 1977.

Ehrlich, P.R. and A.H. Ehrlich, *Extinction*, Random House, New York, 1982.

Eisner, T., "Chemicals, Genes, and the Loss of Species," *Nature Conservancy News* 33(6): 23-24, 1983.

Erwin, T.L., "Tropical Forest Canopies: The Last Biotic Frontier," *Bulletin of the Entomological Society of America* 29(1): 14-19, 1983.

FAO and UNEP, *Tropical Forest Resources*, Rome, Italy and Nairobi, Kenya, Food and Agriculture Organization and United Nations Environment Programme, 1982.

Fearnside, "Human-Use Systems and the Causes of Deforestation in the Brazilian Amazon," Paper presented at *UNU International Conference on Climatic, Biotic and Human Interactions in the Humid Tropics*, Sao Jose dos Campos, Sao Paolo, Brazil, Feb 25th-March 1st, 1985.

Frayer, W.E., and three others, *Status and Trends of Wetlands and Deepwater Habitats in the Coterminous United States, 1950s to 1970s*, Fort Collins, Colorado, Department of Forestry, Colorado State University, 1983.

Fuller, D., "Mexican Trade Dilemma--Plants at Risk," *TRAFFIC* (USA) 6(2): 7-11, 1985.

Gentry, A.H., "Patterns of Neotropical Plant Species Diversity," *Evolutionary Biology* 15: 1-84, 1982.

Hadley, M.; and Lanly, J.P.; "Tropical Forest Ecosystems: Identifying Differences, Seeing Similarities," *Nature and Resources* 19(1): 2-19, 1982.

Hall, A.V.; de Winter, B.; Fourie S.P.; and Arnold, T.H.; "Threatened Plants in Southern Africa," *Biological*

Conservation 26: 5-20, 1984.

Hamilton, L.S. and S.C. Snedaker, (eds.) Handbook for Mangrove Area Management. Environment and Policy Institute, East-West Center, Honolulu, Hawaii, 1984.

Harrison P.; and J. Rowley; Human Numbers, Human Needs, London, U.K., International Planned Parenthood Federation, 1984.

Hillman, K., (former Chairman of the Rhino Specialist Group), African Wildlife Foundation, Nairobi, Kenya, personal communication, 1985.

Houghton, R.A.; and seven others; "Net Flux of Carbon Dioxide from Tropical Forests in 1980." Nature (in press), 1985.

IUCN. Plant Red Data Book. IUCN, Gland, Switzerland, 1979.

IUCN. Global Status of Mangrove Ecosystems. International Union for Conservation of Nature and Natural Resources, Gland, Switzerland, 1980.

IUCN. Mammal Red Data Book, Part I. IUCN, Gland, Switzerland, 1982

Justice, O.L.; and Bass, L.N.; "Principles and Practices of Seed Storage," Agriculture Handbook No. 506, Washington, D.C., Science and Education Administration, Department of Agriculture, 1978.

Mack, D. and R.A. Mittermeier (eds.) The International Primate Trade, Vol. 1: Legislation, Trade and Captive Breeding: 1-83. World Wildlife Fund-US. Washington DC, 1984.

Martin, P.S.; and Klein, R.G.;(eds.), Quaternary Extinctions, London, U.K., Eurospan Publishers, 1985.

Melillo, J.M., et al., "A Comparison of Recent Estimates of Disturbance in Tropical Forests," Environmental Conservation 12: 37-40, 1985.

Molofsky, J., C.A.S. Hall; and Myers, N.; A Comparison of Tropical Forest Surveys, Washington, D.C., U.S. Department of Energy (in press), 1986.

Mori, S.A.; Bloom, B.M.; and Prance, G.T., "Distribution Patterns and Conservation of Eastern Brazilian Coastal Forest Tree Species," Brittonia 33(2): 233-245, 1981.

Myers, N., "The Cheetah in Africa under Threat," Environmental Affairs 5: 617-647, 1976

Myers, N., The Sinking Ark, New York and Oxford, U.K., Pergamon Press, 1979.

Myers, N. 1979. *The Sinking Ark*. Pergamon Press, New York and London.

Myers, N., *Conversion of Tropical Moist Forests*, Washington, D.C., National Research Council, 1980.

Myers, N., "The Hamburger Connection: How Central America's Forests Become North America's Hamburgers," *Ambio* 19(1): 3-8, 1981.

Myers, N., *A Wealth of Wild Species*, Boulder, Colorado, Westview Press, 1983.

Myers, N., *The Primary Source*, New York, W.W. Norton, 1984.

Myers, N., "The End of the Lines," *Natural History* 94 (feb): 2, 6, 12, 1985.

Myers, N., *Tropical Moist Forests: Over Exploited and Under Utilized?*, Report to IUCN/World Wildlife Fund, Gland, Switzerland (in press), 1986.

Ono, R.D.; Williams, J.D.; and Wagner, A.; *Vanishing Fishes of North America*, Stackpole/Stone Wall Press, 1983.

Organization for Economic Cooperation and Development. *Report on the State of the Environment*. Organization for Economic Cooperation and Development, Paris, France, 1985.

Rauh, W., "Problems of Biological Conservation in Madagascar," *Plants and Islands*, Bramwell, D., (ed.), London, U.K., Academic Press, 1979.

Raven, P.H., *Research Priorities in Tropical Biology*, Washington D.C., National Research Council, 1980.

Raven, P.H., Missouri Botanical Garden, personal communication, 1985.

Simberloff, D., "Are We on the Verge of a Mass Extinction in Tropical Rain Forests?," *Journal of Biogeography* (in press), 1985.

Soule, M.E., (ed.), *Conservation Biology Revisited*, Sunderland, Mass., Sinauer Associates (in press), 1986.

Soule, M.E. and Wilcox, B.A., (eds.), *Conservation Biology*, Sunderland, Mass., Sinauer Associates, 1980.

Tiner, R.W., *Wetlands of the United States: Current Status and Recent Trends*, Washington D.C., Fish and Wildlife Service, Department of the Interior, 1984.

Tucker, C.J.; Holben, B.N.; and Goff, T.E., "Intensive Forest Clearing in Rondonia, Brazil, as Detected by Satellite Remote

Sensing," *Remote Sensing of Environment* 15: 255-261, 1984.

Western, D. *Monitoring Africa's Megafauna*. Animal Kingdom. May/June 16-21, 1985.

Wildlife Trade Monitoring Unit, *A Perception of the Issue of High Trade Volume*, Cambridge, U.K., Wildlife Trade Monitoring Unit, Conservation Monitoring Centre, 1984.

Wilson, E.O., *Biophilia*, Cambridge, Mass., Harvard University Press, 1984.

Wilson, J., *Colonization in Rondonia: The Case of Ariquemis*, Doctoral Dissertation, University of Florida, Gainesville, 1985.

World Bank. *World Development Report 1985*. World Bank, Washingtion DC, 1985.